An epidemiological study on the relationship between quality and quantity of social networks and chronic pain in older adults using data from the MOBILIZE Boston Study

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DECLARATION

I certify that the work contained in this thesis, or any part of it, has not been accepted in substance for any previous degree awarded to me or any other person, and is not concurrently being submitted for any other degree other than that of (PhD in Education & Health Sciences) which has been studied at the University of Greenwich, London, UK.

I also declare that the work contained in this thesis is the result of my own investigations, except where otherwise identified and acknowledged by references. I further declare that no aspects of the contents of this thesis are the outcome of any form of research misconduct.

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ABSTRACT

Key words: Pain, Older Adult, Social Network, Mobilize Boston Study

Introduction: Pain is experienced amongst all ages of people. However, the pattern of its occurrence in older people is still not well understood. Existing evidence indicates that older adults are more susceptible to pain than other age groups. Moreover, the older adult population is now the fastest growing in the developed world, due to an increased life expectancy that is predicted to continue rising. There is evidence to suggest that social networks have a beneficial effect on the health and functional abilities of older people. Social networks, the support they provide, and engagement in social activities has been found to exert significant positive effects on the health and general functioning of older persons. In contrast, there is increasing evidence that socially isolated individuals have an increased risk of developing chronic conditions such as depression and impaired cognitive functions. It is therefore important that years lived are accompanied by a highly functional state of health. Understanding how this is achieved would have both individual and societal benefits, putting less economic burden on health care organisations and governments around the world.

Aim, objectives, and study hypothesis: This study aimed to explore if there is an association between social networks, social activities and chronic pain in community dwelling older adults. This was achieved by two overarching objectives, firstly by reviewing the literature to identify if social networks play a protective role on pain outcomes in older community dwelling people; and secondly by analysing an existing dataset (the Mobilize Boston Study) that offered data on pain at baseline and at 18-months follow-up, along with data on structural social networks and social activity measures. It was hypothesised that the Mobilize Boston Study dataset would demonstrate social network and activity to be protective against pain outcomes (severity and interference).

Methods: Firstly, a review of literature was conducted and the included studies were analysed and synthesised using a narrative synthesis. Secondly, a secondary data analysis on self-reported measures of structural social networks, social activity and pain outcomes from the Mobilize Boston Study dataset, a prospective cohort study of 749 older adults aged 70 years and over, was conducted. Descriptive statistics were used to characterise the cohort at baseline. Chi-square statistics were conducted to categorise baseline cohort characteristics according to each social network and activity measure. Hierarchical regression models were run on baseline measures of social networks and activity, and pain outcomes, accounting for potential confounding covariates (e.g., socio-demographic and health factors). Longitudinal analysis using social networks and activity measures at baseline to predict pain outcomes at 18-months follow up was also conducted.

Results: The findings from the literature review concluded that social activity was related to better pain outcomes in older adults, however measures of perceived social support or structural social networks did not influence pain outcomes. The secondary data analysis demonstrated that the quantity of social networks did not play a role in predicting pain outcomes, whereas the social activity scores independently predicted lowered pain interference with daily activities, even after adjusting for potential confounding factors such as age, sex, race, education, difficulty in mobility, and depression. For pain severity, neither quantity of social networks nor social activity scores demonstrated any significant associations. The relationship between baseline social network and social activity scores with pain interference and severity outcomes over 18 months did not generate statistical significance after accounting for health factors.

Conclusions: The results concluded that higher social activity predicts lower concurrent pain interference, but there was no evidence for the role of social networks on pain outcomes. Health variables such as depression were strongly related to pain and significantly confounded the relationship between social networks and pain outcomes, both in severity and interference. This suggests that future research on pain should focus on qualitative aspects of social networks and pain in older adults, and in particular on older individuals free from depression. Aspects of social activity that make it protective for pain interference such as that defined by physical activity should be investigated further to confirm the findings of this research; non-pharmacological interventions designed to improve pain interference should focus on older adult’s social and physical activity.

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1. INTRODUCTION

This chapter provides an introduction and overview of the thesis, alongside contextual background information on the researcher. It sets out to give the reader a sense of the research in its entirety, and chapter by chapter. Subsequent chapters provide more detail on each aspect of this study.

1.1 Significance of the research

There has been a major improvement in life expectancy globally over the last century, and it is therefore crucial for governments and public health organisations that this longevity is accompanied by healthy years of life and a reduction in age-related diseases (Chang *et al.*, 2019). Demographic trends projected during the start of the century indicated a considerable ageing of the world's population (UN, 2004). All the more, this phenomenon has been rising since the end of last century largely due to a decline in mortality in people aged over 65; life expectancy is therefore expected to continue rising (Guralnik and Kaplan, 1989). These changes in the age structure of a population have been reported largely due to revolutions in life expectancy, dynamics in fertility and migration (Christenson *et al.*, 2009). In the UK, since the start of the nineteenth century, mortality rates have declined in the over 65's and subsequently life expectancy has increased (ONS, 2018). However, life expectancy has risen quicker than healthy older ageing (PHE, 2018). For these reasons, epidemiological studies on ageing have focussed on identifying potential factors that not only benefit longevity but also support independent living (Guralnik and Kaplan, 1989). However, there remains sparse evidence on whether increasing longevity is accompanied by an extended period of good health (Beard *et al.*, 2016). Furthermore, whether increased longevity is treated as an opportunity or a threat to the stability of societies depends not only on how long populations live but also on whether they experience the negative health effects of ageing such as physically, socially, and mentally (Lopez-Otin *et al.*, 2013). Trends in individual societies indicate a considerable ageing of their populations and subsequently associated burdens on their resources (e.g. Germany), and a constant rise in direct per-capita utilization due to an ageing society (Dallmeyer *et al.*, 2017). Therefore, governments globally are trying to introduce policies that address ageing in their societies (Chang *et al.*, 2019).

There has been accumulating evidence that with increasing age, the prevalence of chronic pain is expected to increase (Blyth *et al*., 2001; Johannes *et al*., 2010). Chronic pain, affects older people's performance in undertaking daily activities (Helme and Gibson, 1997; Reyes-Gibby *et al*., 2002; Thomas *et al*., 2004; Bryant *et al*., 2007). It has been proposed that chronic pain affects older people more than younger people (Helme and Gibson, 2001). Although musculoskeletal pain is a prevalent health challenge for all age groups worldwide, it is most notably in older adults (Smith *et al*., 2014); and can lead to functional dependence (Bryant *et al*., 2007; Leveille *et al.,* 2009). Functional dependence further leads to disability (Cleeland, 2009), and this chronic pain-related disability due to functional dependence has been associated with a decrease in healthy ageing (Wilkie *et al*., 2013). The functional dependence occurs more often due to pain that strikes the lower limbs; the occurrence of such site-specific chronic pain has been shown to be more prevalent in older people (Leveille *et al*., 2009; Docking *et al*., 2011). Several studies have linked pain in specific sites such as knee pain and lower back pain to functional disability (Cecchi *et al*., 2009, Kovacs *et al*., 2008). Therefore, older people who suffer from pain in multiple sites are more vulnerable to functional consequences.

There is a further potential for greater disability risk in the older population due to central mechanisms, where cognitive effects interfere with mobility due to chronic pain. Literature over the past two decades on pain and functional dependence in older adults has stimulated an investigation into potential protective factors for pain in this age group. One such factor, the influence of quality and quantity of social networks in the development and progression of disabilities in older adults, has emerged as an important concept in ageing cohorts (Peat *et al*., 2004; Richardson *et al*., 2015; Leung *et al*., 2015). Social networks, engagement in social activities and social support, in particular, have been conceptualised to exert positive effects on the health and general functioning of older persons (Berkman *et al*., 2000, Unger *et al*., 1999; Peat *et al*., 2004; Jakobsson *et al*., 2003). Therefore, this epidemiological study will aim to explore the role of social networks and social activity on pain outcomes in older adults, and to identify the benefits of visual and non-visual social networks on the older adult experience of pain severity and pain interference. It is hoped that this knowledge could help inform interventions designed to reduce the negative experience of pain in older people.

There are very few comprehensive studies investigating the role of social networks and social activity on chronic pain outcomes (both severity and interference) in community dwelling older adult populations (Peat *et al*., 2004; Weisman *et al*., 2014; Leung *et al*., 2015; Richardson *et al*., 2015). This thesis provides a detailed and complete definition of the social network variable, including both its structure and function, based on the concepts laid down by Glass *et al.* (1997). It is informed by theory on social networks and health outcomes from the literature (Berkman *et al.,* 2000), and investigates the effect of social networks and activity on chronic pain experience in older people. This study takes a deductive approach and proposes a hypothesis in line with the theoretical model of social networks and health outcomes proposed by Berkman *et al.* (2000) and uses social network and social activity variables from Berkman *et al.'s* (2000) theoretical framework to test their relationship with pain outcomes using data from the Mobilize Boston Study (MBS). The MBS is a large representative dataset of older adults, with baseline measures of social network, and baseline and 18-month follow up data on pain outcome variables. The findings generated both from cross sectional and longitudinal data will help identify temporal relationships between social networks/activity and pain outcomes, which can help inform policy and practice on the management of pain experiences in older adults.

1.1.1 The importance of research on older adults

Ageing population

The older adult population is currently the fastest growing globally (Docking *et al*., 2011). The 'older adult' is categorised as any individual above the age of 60 years in developing nations and 65 years in developed nations as described by the World Health Organisation (WHO), 2010. According to Gorman (2000), 60 or 65 years of age is roughly equivalent to retirement age in most developed nations. However, in contrast to chronological milestones that mark the life stages in most developed countries of the world, the idea of old age in developing nations begins at the point when active physical contribution is no longer possible (Gorman, 2000).

In the United States (US), the relative percentage of older adults is continuing to grow at 1.5 times the average rate, and those over 65 are expected to make up 20% of the total population by 2030 (Molton and Terrill, 2014). In the UK, the population is also ageing, and it is estimated that the percentage of older adults (65 and above) will increase by more than one-third (16% to 22%) by 2031. It is estimated that the proportion of older adults (>65 years of age) will have exceeded those <25 years of age in the UK by 2031 (Kumar and Allcock, 2008). These statistics demonstrate that older adults are living much longer. It is imperative therefore, that the increase in years lived is accompanied by successful ageing and a highly functional state of health (Guralnik and Kaplan, 1989; Leveille *et al*., 2009; Matos *et al*., 2016).

Chronic pain in older adults

Pain is experienced by all ages in a population. Studies have demonstrated that chronic musculoskeletal pain affects older people's health and well-being substantially and is associated with a decreased quality of life and increased consumption of health and social care resources (Dawson *et al*., 2005). However, there remains uncertainty about the pattern of its occurrence, etiological factors, and its related morbidities in older people (Kumar and Allcock, 2008). In the US, 60%–75% of people over the age of 65 report at least some persistent pain, and this rate is considerably higher for people who are in assisted living facilities or nursing homes (Molton and Terrill, 2014). Older people are more susceptible to pain than any other age group in the UK population with an estimated 50% of the population over 65 experiencing some form of pain or discomfort, (Kumar and Allcock, 2008). According to the population division publications of the United Nations (2013), it is estimated that chronic pain affects 50% of the population aged 60 and above. However, it is suggested that back pain affects younger adults more than older adults owing to the hypotheses that correlates back pain to working age and work-related physical factors. Conversely, it is reported that disabling back pain or severe back pain affects older adults more compared to younger adults (Thomas *et al*., 2004). Thomas *et al*. (2004) also reported that the onset of pain that interferes with everyday living increases with age.

It is acknowledged that opinions about persistent pain and its consequences vary between younger and older adults as suggested by Davis *et al*. (2002). They also propose that older adults in community dwelling settings are more likely to cultivate a mistaken belief about pain being inevitable in later years of life. Older adults in nursing homes, along with their care providers, develop expectations that pain increases with age (Brown and Williams, 1995; Ferrell, 1996). Older adults in general tend to develop impassiveness towards pain and this in some cases discourages them from seeking help for persistent pain conditions (Davis *et al.*, 2002). Chronic pain is very common among this population and leads to a tremendous burden on the individual, family and society (Leveille *et al.*, 2009, Bruckenthal *et al.*, 2009). Additionally, chronic pain is reported to affect 50% of community dwelling older adults and is even higher in nursing home residents - around 80% (Helme and Gibson, 2001). This could be because it is more likely to be neglected by older people living in community settings, as they tend to believe that it an inevitable part of ageing (Davis *et al*. 2002). Chronic pain that is left untreated, can lead to many debilitating consequences such as widespread musculoskeletal pain, functional immobility and even disability (AGS, 2002; AGS, 2009; Leveille *et al.*, 2009; Bruckenthal *et al.*, 2009).

In summary, it can be assumed that the older adult's experience of pain differs from that of younger adults in many ways. This is in relation to their life context, which includes retirement, changes in function, grief, sorrow and isolation (Bruckenthal *et al.*, 2009). There is an added burden owing to multiple age-related diseases and conditions in older adults, which complicates their management of pain (Bruckenthal *et al.*, 2009). Moreover, there is a greater risk of older adults with pain developing depression (Turk *et al.*, 1995) and physical impairment (Wittink *et al.*, 2006). Pain is therefore an important issue for older adults, which require further recognition and attention due to the world's ageing population.

Chronic pain consequences in older adults

Longitudinal studies using global pain assessments have established that higher levels of chronic pain are significantly associated with diminished mobility and subsequent disability in selected groups of older adults. The groups of people included in these studies were older adults in religious orders, residents of retirement communities, older women with disabilities, and individuals receiving home care (Buchman *et al.*, 2010, Shah *et al.*, 2011, Soldato *et al.*, 2007, Leveille *et al.*, 2007). Published research on the effects of chronic pain in older adults is accumulating. The functional effect of chronic pain in older adults is a gradually developing problem whereby it leads to a deteriorating function over time. This issue has gained increased urgency due to the rapid growth of the older population in recent decades (Docking *et al*., 2011); and pain related disability among older adults has a clear economic burden in terms of healthcare resources, caregiver, individual and societal burdens (Leveille *et al.,* 2009). This has generated a motive for more research on the subject of chronic pain in older adults. Hence, along with a requirement for effective long-term management of chronic pain conditions, it is vital to focus on both risk and protective factors that predict chronic pain outcomes in this population.

The issue of chronic pain is exacerbated by evidence that its management in older people is often limited and inadequate (AGS, 2002; Bruckenthal *et al*., 2009, Leveille *et al*., 2009; Stewart *et al*., 2012). Acute pain management focuses on treating the cause, but persistent or chronic pain management is much more complex and requires the involvement of older adults to manage their pain on a daily basis (Grichnik and Ferrante, 1991). Self-pain management is actively promoted for persistent pain and is endorsed by clinical guidelines and clinicians (AGS, 2002). However, even after engaging in various pain management approaches, older people often report the approaches as ineffective (Barry *et al*., 2005). One possible reason for this is that understanding and remembering pain management advice becomes challenging for the cognitively impaired older adult (Isaac and Tamblyn, 1993). This may lead to a suboptimal treatment approach for highly prevalent persistent pain, which generates a limited and inadequate approach to managing later life pain (Stewart *et al*., 2014).

Social relations and activities in older adults

Research on social networks became the focus of attention back in the 1980s with much regard to their possible protective role on health and wellbeing (Seeman and Berkman., 1988). Early research on social networks and health was mostly based on secondary analyses of existing data on measures of social ties (spouse, children, close friends and relatives) addressing the hypotheses that better health outcomes were associated with the support these ties provided (Seeman and Berkman, 1988). Thus, the assumption was made that social network ties represented sources of support (Berkman, 1986). In the case of older adults, however, some of these ties (spouse or friends) that would provide support when younger, themselves experienced some sort of disability with increasing age. This can lead to a lack of social support from such social ties with increasing age (Seeman and Berkman, 1988). Therefore, it was essential to identify those ties or sources that would provide social support to older people in order to plan successful social network interventions to positively influence their health. The literature to date contains substantial evidence indicating the health benefits of social integration. For instance, people with more social ties are reported to have a lower risk of mortality (Stephens *et al*., 2011). On the contrary, poor social connections, fewer social activities, and social disengagement in older adults has been linked to a greater risk of cognitive decline (Zunzunegui *et al*., 2004). Cognitive functioning is a vital determinant of the quality of life among older adults in maintaining independent living, and considerable individual differences exist in rates and timings for this decline among the older population (Seeman *et al*., 2001).

There is increasing evidence that socially isolated individuals have an increased risk of developing other chronic conditions such as depression (Harlow *et al.,* 1991, Oxman *et al.,* 1992, Koizumi *et al*., 2005, Chan *et al*., 2011), cardiovascular diseases (Barth *et al*., 2010), and infections (Heeler, 1997). Many studies support the assumption that social network factors such as social support and social engagements are all important in the maintenance of health and wellbeing (Berkman and Glass, 2000, Zunzunegui *et al*., 2004). These include positive associations of social networks or social engagements with cognitive functions (Seeman *et al*., 2001), disability (Mendes de Leon *et al*., 1999, Escobar-Bravo *et al*., 2012), functional autonomy among the elderly (Mendes de Leon *et al*., 2003, Avlund *et al.,* 2004a, b), and mental wellbeing (Chan *et al*., 2011).

1.2 Research rationale

The motivation for this study comes from the body of research that has identified associations between social networks and health outcomes within an ageing population, coupled with rising chronic pain experiences, and advancements in research on social networks and their health benefits in older adults.

Health benefits of social integration and social support have been demonstrated by Seeman *et al*., (2001) who examined its relationship with cognitive functioning in the MacArthur Studies of Successful Ageing. Findings suggested that one's social environment (social ties, emotional support) is protective against cognitive decline in older age. This PhD explores the concepts laid down by Berkman *et al*. (2000) on the role of social networks on health outcomes and extends this theory to pain outcomes.

This conceptual framework was used previously to investigate associations between social networks and self-rated health in older adults (Zunzunegui *et al*., 2004). These studies provide evidence that social networks play an important protective role in health and disease outcomes in older adults, and hence should be explored in relation to pain outcomes. More recently living alone and having a greater number of social contacts outside the household in the Singaporean older adult population has shown significant associations with pain onset and progression (Leung *et al*., 2015).

Associated factors such as loneliness have also been identified as predictors of chronic back pain onset (Jacobs *et al*., 2006). Another study done in England on middle and old age adults demonstrated that an absence of close friends and absence of close relatives for women are associated with pain that interferes with daily living (Peat *et al*., 2004). These findings provide a clear rationale for a hypothesis that a better social environment (e.g., larger social networks and higher social activity) will predict lesser pain outcomes in older people. However, before testing this hypothesis, an initial literature review will be conducted to determine the extent of knowledge on social networks and pain outcomes in the extant literature, in order to provide a clear, evidence-based rationale for the investigation of social networks and activity in older adults, and their relationship with concurrent and future pain outcomes.

Additionally, an association between social networks and activity with pain outcomes in older adults has clear relevance for public health interventions. This can be achieved by providing evidence for the relationship between social networks/activity and pain, which can inform policy and practice within the health care profession in terms of managing pain in later life. This is especially necessary given increasing evidence that socially isolated individuals have an increased risk of developing other chronic conditions (Heeler, 1997; Eng *et al*., 2002; Barth *et al*., 2010; Chan *et al*., 2011). These chronic conditions and their debilitating consequences in older adults result in a considerable personal burden to care givers, as well as heavy economic and financial costs to the individual and society and to the country as a whole (Leveille *et al*., 2009, Bruckenthal *et al*., 2009; Dallmeyer *et al*., 2017). Health researchers and public health professionals involved in policy-making can benefit from a better understanding of the protective nature of social networks and social activity on pain outcomes, and how a protective role can be systematically incorporated within pain management programmes for older people that involve their family, society, medical professionals and health care providers. Enhanced pain management programmes can in turn help develop more functional independence in older adults, because even though it has been assumed that functional ability decreases overall with age, there is considerable heterogeneity and variability in the rate of functional decline in older adults (Rowe and Kahn, 1987, Beckett *et al*., 1996). Participation in physical activities for older people has shown to improve wellbeing; and social activity has not just been the outcome but a contributor to healthy ageing (Richardson *et al*., 2015).

1.3 Theoretical framework and study measures

A range of causal processes have been proposed by Berkman *et al*. (2000) to demonstrate the connection between social relationships and health. They proposed the existence of a causal connection between health and social networks that is mediated by "upstream" and "downstream" factors. Socio-cultural and environmental conditions (such as socio-economic status, race etc.), social network structure and function form the upstream factors; whereas downstream factors include psychosocial mechanisms such as behaviour, social engagement or activities, social support and access to material resources. The current thesis is based on these basic concepts put down by Berkman *et al.* (2000) through which both social network (structure and function) and social activity influences health (chronic pain), with a general hypothesis that there will be a positive influence of social networks/activities on chronic pain outcomes, and thus functional ability, of older adults. Social networks are defined by their structure and function. Structure is defined by the number of social ties an individual has, and the proximity of these social ties – whether they are visual (e.g. meeting with relatives and/or friends in person), or non-visual (e.g. correspondence with family and/or friends). Function is defined by the frequency of contact with social ties, as well as the reciprocity of support from social ties. Social networks can be further classified based on their role into sub-networks (friends, relatives, children, spouse). These networks may generate support, which can be a mediating factor between network ties and health outcome (Zunzunegui *et al*., 2004). Social engagement is defined as community involvement such as belonging to a neighbourhood or religious groups (Berkman *et al.,* 2000, Zunzunegui *et al*., 2004), maintaining many social connections and a high level of participation in social activities (Bassuk *et al*., 1999). Therefore, both social network structure (non-visual) and function (visual) and engagement in social activities were used as predictors of pain outcomes in the current study analysis using the MBS dataset.

The MBS dataset has information on both these variables (social network and social activity) required for this study, as well as on pain outcomes. Social network was a set of nine questions, based on the social network index (Glass *et al*., 1997). These questions were classified into non-visual social network and visual social network, with an additional variable of someone to depend upon (confidante). Grouping and coding of these questions regarding social network of the participants were based on the social disengagement index (Bassuk *et al*., 1999). A set of eight questions and a social activity score (calculated from these questions) was used to define the social activity variable by the MBS. Pain measures used to define these pain outcomes used in the current study were BPI pain severity and BPI pain interference subscales (Cleeland, 1989).

1.4 Research aims and objectives

The overarching aim of this research was to explore the role of social networks and social activity on pain outcomes in older adults, and to identify the benefits of visual and non-visual social networks on the older adult experience of pain severity and pain interference. To achieve this, two objectives were set. The first objective was to conduct a review of the literature on the relationship between social networks/activities and pain outcomes in older adults. The second objective was to investigate the relationship between social networks and activities and pain outcomes in older adults by conducting a secondary data analysis of the MBS dataset. In order to achieve the second objective of the study, a social network variable was created based on research by Bassuk *et al*. (1999), using information from the MBS on social ties (number and frequency of seeing children, relatives, friends, and presence of a confidante). In addition, scores for the BPI pain interference subscales were calculated. An initial characterisation of the cohort was conducted using descriptive, independent and dependent variables to describe the sample. This was followed by two inferential statistical analyses, a correlational analysis and multiple regression analysis to identify associations between social networks/ social activity and chronic pain outcomes in older adults, and a multiple regression analysis to understand the influence of baseline social networks/social activity on pain outcomes at 18-month follow-up. Identification of the positive role of key social factors on pain experience will have implications for public health policy and practice. An enhanced understanding of the relationship between social networks and pain can inform more cost-effective, non-medical interventions to support the management of chronic pain over time among the older adult population. Although more is known about the positive effects of social networks on psychological and physical health of older people, relatively little is known about the positive effects of social networks on pain outcomes in the older adult population. Evidence from the current thesis can better inform health care professionals and supplement more expensive pharmacological treatments to support older people in managing their pain.

1.5 Research approach

This research has taken a deductive approach, based on Sneider and Larner (2009), that started with exploring a theoretical framework on social networks and health changes as described by Berkman *et al.* (2000), and then defined and classified social networks based on Glass *et al.*'s (1997) framework. This informed the research strategy for investigating associations to test the general hypothesis that strong social networks and greater social activity scores are associated with lower pain severity and interference outcomes. Analysis was conducted using data from a sample population of older adults recruited into the MBS study; using measures collected at baseline and 18-month follow up. If a correlation between variables is evidenced from the literature or a causal relationship implied from a theory on these variables, then a deductive design can help to find links (if present) on more general circumstances (Gulati, 2009). Therefore, the advantages of such an approach are the potential to generalise result findings and the potential to quantitatively measure concepts.

1.6 Thesis structure and overview

This thesis is the result of my PhD journey over the last six years. It is arranged in the form of chapters that inform and compile the work conducted, and milestones achieved in relation to my research topic, '*An epidemiological study on the relationship between quality and quantity of social networks and chronic pain in older adults using data from the MOBILIZE Boston Study'*. This **first introductory chapter** informs the reader about the background of the research, significance, indications and rationale. It sets the stage for the research by contextualising the aims and objectives of the study and steps undertaken to achieve them.

The **second chapter** reviews the literature, highlighting the problem of chronic pain, its burden on society and describing the definition of pain, the history of pain models, classifications and measurements, epidemiology, prevalence and risk factors in older adults. The second chapter explores the concept of social networks and health, and its complexities in older people. Terms interchangeably used for social networks such as social support and social relationships are all discussed in the context of the studies conducted in the literature. Social engagement or activity is explored in close connection with social networks in the older population. Measurements used in the literature to define and assess a social network or activity of older adults is explored. This chapter also provides a greater understanding of social networks and its benefits on various health outcomes in older people such as depression, cognitive impairment, and disability and the qualitative aspect of social networks describing loneliness and its role in older people.

The **third chapter** is a follow-up on social networks and health, describing the concepts of social network. This chapter puts forward the conceptual framework for this study. It describes the theoretical framework consisting of social networks and health outcomes, where both upstream and downstream pathways play an important role in health and disease outcomes. This chapter also guides and provides a rationale for generating the hypothesis for the study, that is, that larger social networks and activity are associated with lower pain outcomes. It also outlines the research aims and objectives.

The **fourth chapter** is a literature review. It is a step-by-step description of the literature search, selection criteria, and relevant studies shortlisted and then finally included as eligible studies for the review. It defines the measures taken to check the quality and risk of bias of the included studies. Tables wherever necessary have been presented with results. This chapter also provides details on data extraction and results synthesis from the included studies on the research question.

Chapter five is the methodology chapter. It starts with a description of various types of epidemiological study designs, then numerous concepts in epidemiology are briefly described, and lastly the theory on secondary data analysis are presented and reviewed alongside its strengths and limitations.

Chapter six is the methods chapter. It begins by briefly describing the Mobilize Boston Study and explains the current study design, data collection (choosing variables, creating new variables etc.) and data analyses conducted to achieve the second objective of the study. Both baseline data and 18-month follow-up data are provided by the MBS dataset to test associations between the key independent and dependent variables of the study.

The **seventh chapter** presents the results of the secondary data analysis of the Mobilize Boston Study dataset, testing the hypothesis that larger social networks and greater scores of social activities are associated with lower pain outcomes, both pain severity and pain interference, in community dwelling older people.

The **eighth chapter** is a general discussion of the results, summarising the main findings, consideration of the results within the context of theory and research in the field, assessment of the main strengths and limitations of the study, future research recommendations, and the implications of results for policy and practice.

The final **ninth chapter** provides conclusions inferred from the overall study.

1.7 Research outcomes

A review of literature on the association between social networks and activities on pain of older people living in the community resulted in a total of nine included studies. The overall findings of this review demonstrated that social networks outside the household and engagement in meaningful social activities were found to be protective against pain interference. However, for most of the studies included in the review, health comorbidities such as depression and stress overshadowed the benefits of social ties, support they provided and social activities.

The results of the secondary data analysis of the Mobilise Boston Study have demonstrated that 25% of the MBS cohort were affected with moderate-severe pain outcomes (severity and interference with daily activities). Females were more prone to pain severity and interference than males in this sample. The key outcomes of this research were that non-visual social networks, visual social networks, someone to depend upon and social activity scores had no significant associations with pain severity in final regression models; whereas pain interference scores and social activity demonstrated significant associations. Further on, non-visual and visual social networks both demonstrated significant associations only with pain interference scores after accounting for socio-demographics in unadjusted regression (without accounting for mobility difficulty and depression in the regression model), but in the final adjusted models this association became non-significant. The only significant association was between social activity scores (p=0.024) with pain interference outcomes even after accounting for socio-demographic as well as health (mobility difficulty and depression) factors in the regression models.

The covariates that showed significant associations with the pain severity outcome in adjusted regression were age (p=0.007), sex (p=0.000), education (p=0.000), mobility difficulty (p=0.000) and depression (p=0.046). Those that remained significant predictors for pain interference outcome in adjusted regression models were sex (p=0.010), education (p=0.006), mobility difficulty (p=0.000) and depression (p=0.000).

Another critical research outcome was that, baseline social activity scores independently predicted pain interference at 18-months follow-up in this population in unadjusted (p=0.007) as well as when adjusted for socio-demographic variables (p=0.012). This remained significant even when mobility difficulty was accounted for in the regression. However, when depression scores were entered into the hierarchical regression; the association was near significant (p=0.078). The result findings demonstrate that for this sample population, higher scores of social activities at baseline predicted lower pain interference over time even when accounting for the confounding actions of significant covariates. However, depression masked the favourable effects of social activity in predicting lowered pain interference in daily activities at 18 months follow-up.

1.8 Research contributions

Pain is a burden not just to the individual but society as well, and therefore it is important to identify its protective factors. The literature provides evidence on the protective role of social networks on chronic disease outcomes such as cognitive impairment, disability in older adults, mental and physical health, and hence, this study hypothesised that it will play a protective role on pain outcomes. However, it was important to identify any prior studies conducted investigating these relationships in older people. Therefore, this research contributes towards the first literature review on associations between social networks/activity and pain outcomes (severity and interference) in community dwelling older people; thereby bridging the gap in literature.

The large representative dataset from the MBS and its quantitative data analysis contributes towards generalising the results to similar populations of community dwelling older adults aged 70 and above. It was concluded that social activity was protective against pain interference in older people. This is an important research implication since both policy makers and public health professionals can implement community engagement programmes promoting functional autonomy and mobility by including social and leisure activities. In managing later life pain and in-turn functional dependence for ADL (Activities of Daily Living) and IADL (Instrumental Activities of Daily Living), medical professionals can focus on psychosocial therapy along with the pharmacological management of pain, advocating a bio-psychosocial model of pain experience. For older people residing in nursing homes, non-pharmacological management of pain includes engagement in activities with the other residents and formal social support from the staff. Caregivers and social workers are being trained to incorporate supportive behaviours that promote older adult's functional autonomy to engage in leisure and physical social activities with other residents. These point towards the role of physical autonomy and independence in managing later life pain.

The study also contributes towards knowledge advancement in respect to identifying an existing conceptual framework postulated in the literature explaining the role of social networks and activity on health outcomes and utilising this model to generate hypothesis for pain outcomes in older adults. Further on it enhances information on Berkman's conceptual model by first conducting a literature review and then the MBS analysis both of which provide conformity to this framework by demonstrating evidence to substantiate the interactions played between social constructs and health as proposed by the authors of this framework. Nonetheless, this was possible since the MBS dataset provided variables that aligned closely with the factors in this model. However, it being a secondary dataset, there were some variables that fitted closely into the model and some were not available, therefore the model was employed to predict pain outcomes through the current study analyses. The current research establishes the protective role of upstream factors (macro such as race, education) and downstream factors from that framework (micro such as high social activity scores) on chronic pain interference outcome in older adults.

1.9 Scope for future research

The dataset utilised for this study could not establish significant associations between most of the measures of social network (size, frequency of visit, having a confidant) and pain outcomes in both cross-sectionally and longitudinally after accounting for health variables (mobility difficulty and depression). Therefore, studies in future should focus on relationships between pain, depression and social networks. There is scope for future research on aspects of social networks such as loneliness in relation to pain outcomes. Also, since information on the social network and activity variable were not present for the follow-up period in the MBS dataset, it could not confirm whether change in those networks affected the results of the analyses that predicted change in pain outcomes over time from baseline social networks. Therefore, a study with information on varied social network and activity measures over time would investigate the concurrent role of changing social networks on pain outcomes especially pain interference outcomes.

In addition, using different statistical analysis methods to come to conclusions about associations would add to the credibility and robustness of the findings of this study's analysis. A more sophisticated analytical approach of structural equation modelling (Sturgeon *et al*., 2013) or multilevel modelling (Lee *et al*., 2016; Mallon *et al*., 2021) could be adopted in future research.

1.10 Researcher's background

This section of the thesis has been written in the first person for a better comprehension.

Professional achievements and experience: Having done a bachelor's degree in dental surgery (BDS) in India, I have since been practising clinical dentistry, before pursuing my post-graduate education in the UK. My interests have always been in community and preventive dentistry along with an inclination towards diseases of oral cavity (oral medicine), smoking problems and other chronic health problems. This cultivated in me an interest towards public health issues related to dental and overall health. Once I found my passion for public health I volunteered to work part time as a community dentist for school children in collaboration with community health centres back in India. My next step was to undertake a master's programme in my field of expertise and passion. The MSc. in Dental Public Health, Barts school of dentistry, QMUL, UK helped me to achieve that. It also gave me the opportunity to engage in public health modules, and to work on a nationally representative, ELOHI (East London Oral Health Inequality) dataset for my master's dissertation; where I gained excellent knowledge and experience of secondary data analyses and quantitative research methodology. I wanted to further my understanding and career in health research and pursue a career in academia by undertaking a PhD in public health. Ageing, and issues related to ageing, were already familiar to me from my experience in the medical field, hence I grabbed the opportunity to work on a project using the MBS (Mobilize Boston Study) dataset for epidemiological association studies between social networks and pain experience in older adults.

The following sections highlight some of my key skills, courses completed and academic awards and achievements that have helped me to conduct this PhD.

Skills

- Research skills in quantitative and qualitative methods.
- Technical expertise in Microsoft office and Excel, and proficient in using SPSS.
- Academic skills in teaching and learning utilising the Teaching Backwards approach of Griffith and Burns (2014). Including different learning approaches such as blended and flipped learning, and also advocating digital literacies.

Courses and awards

- Online Epidemiological Methods Course in Biostatistics through Non-Degree Graduate Nursing-780 Summer Program, University of Massachusetts, Boston
- Online Biomedical Research Ethics Training through CITI Program, University of Massachusetts, Boston
- Post Graduate Research Teaching, Learning & Assessment Course, University of Greenwich, London

- Awarded Assistant Fellowship HEA GOLD accreditation, University of Greenwich, London

Conference papers

- *Healthy Mouth in a Healthy Body*-Oral Health Promotion Plan for secondary school children in Tower Hamlets, Barts Dental School, QMUL Annual Conference (2014)
- *Larger social networks predict lower pain outcomes*-Problem of Pain in a community dwelling ageing population, Department of Health and Education, University of Greenwich Annual Conference for School of Health & Education (2017)

Research publications

- Anjum, M., Gillam, D. G. and Marcenes, W. (2020), 'Can Tobacco consumption explain the association between SEP and chronic periodontitis in adults living in deprived area of the UK? a secondary analysis of the ELOHI study data', *ES Journal of Dental Sciences*, 1(2), pp. 1-8.

Research manuscripts in preparation for publication

- *Social networks and social activity play a protective role on pain interference outcome and functional disability in older adults using the Mobilize Boston Study dataset*
- *A Review of Literature on identifying the role of social networks and social activity on chronic pain outcomes in older people*

1.11 Chapter summary

This chapter has given an insight into the research that has been conducted for this PhD, and to the researcher who conducted it. The following chapters will go into more detail on the areas discussed in this chapter.

2. BACKGROUND LITERATURE

2.1 Chapter overview

This chapter presents three key areas of focus in relation to social networks and chronic pain in older adults. The first section introduces the definition of pain and in particular chronic pain, as well as a definition of older adults, followed by a consideration of the economic burden of chronic pain on an individual, society, and the country as a whole. It then identifies and critically appraises the different models of pain and chronic pain alongside describing the development of pain theories and the current thinking in this field. Finally, it provides a description of the assessment of chronic pain and the standard instruments used to measure it. This is necessary prior to exploring studies on chronic pain prevalence and risk factors, as it forms the basis to understanding different domains of chronic pain assessed in these studies. The second section of this chapter aims to explore and describe chronic pain epidemiology (both prevalence and risk factors) in older adults. The final section explores and critically appraises evidence from the literature on the protective role of social networks and social activity on health outcomes in the older population.

Chronic pain epidemiology in older adults (>65 years) is discussed in order to provide a broader understanding of the extent of the problem and to identify its risk factors. This section provides a review of the current literature available in areas of pain prevalence and pain risk factors (aetiology) in the older adult population. Since the key variable under investigation is social network/activity, the last part of this chapter will briefly explore and discuss its protective role on health outcomes in older adults providing evidence from the literature.

2.2. Introduction

To explore the background literature on chronic pain experiences, its risk factors and onset/prevalence in older adults, it is necessary to define both chronic pain and the older adult population. Moreover, to explore the established burden of chronic pain on health outcomes in older adults, an estimate of its economic burden needs to be identified. To appreciate the current thinking on the subjective nature of pain and chronic pain in particular, a brief exploration into the historical development of pain theories is useful. Lastly, to understand different domains of chronic pain, a brief explanation of chronic pain assessment is provided.

2.2.1 Definition of pain

Pain is defined by the International Association for the Study of Pain (IASP, 1979) as, *"an unpleasant sensation or emotional experience, which is associated with actual or potential tissue damage or is described in terms of such damage"*. It is one of the most common reasons for seeking medical attention and hospital admission. Chronic pain is described as a complex physical and psychological phenomenon that is persistent and lasts longer than three months and may not have a recognisable cause (Jakobsson *et al*., 2003, Stewart *et al*., 2012).

2.2.2 Definition of older people

The definition of an "older person", as accepted and used by countries of the developed world is, '*any individual above the chronological age of 65 years'* (World Health Organization, 2010). It is also associated with the age when an individual becomes eligible to receive pension benefits (World Health Organization, 2010). The United Nations (UN) agreed upon 60+ years (United Nations, 2013) as the age cut-off for an older person. According to Gorman (2000), 60 or 65 years of age is roughly equivalent to retirement age in most developed nations. However, in contrast to chronological milestones that mark the life stages in most developed countries of the world, the idea of old age in developing nations begins at the point when active physical contribution is no longer possible (Gorman, 2000).

2.2.3 Overview of the global effect of ageing

It is anticipated that by the year 2031, the population of older adults (65+ years) in the UK will increase by more than one-third and make up for 22% of the population (Kumar and Allcock, 2008). One in five persons in the UK will be aged 65 or older by the year 2030 (ONS, 2017). In the next 50 years it is projected that people aged 65 and over will be adding 8.6 million to the total population in the UK, a figure equivalent to the population of London (ONS, 2018). In the US the older adult (65+ years) population is growing 1.5 times faster than the average growth of the population and by the year 2025 or so, it will make up for 20% of the total population (Molton and Terril., 2014). Governments worldwide have urgently been prioritising and introducing policies that address population ageing. Increased longevity is a threat or a strength to the stability of a society and is not just based on living longer but also by ageing without its negative health consequences on mental, physical and cognitive well-being (Chang *et al*., 2019). Since the frequency of pain in community dwelling older adults is reported as increasingly high (Helme and Gibson, 1997; Pareira *et al*., 2004; Azevado *et al*., 2012; Leung *et al*., 2015), the data on the population growth of older people has serious and concerning implications. An ageing society poses a major challenge for health care systems and public health organisations around the world (Dallmeyer *et al*., 2017). For instance, older people tend to be more physically inactive; hence the economic costs of inactivity are likely to increase notably causing financial burden to the individual, society, and the government (Dallmeyer *et al*., 2017). It is therefore important that we measure the extent to which age-related disease burden occurs in a population over time to inform better policies.

2.2.4 Economic burden of chronic pain

Chronic pain is a public health concern that affects 20–30% of the population in developed countries. In the United States, chronic pain alone is estimated to affect 30% of the adult population (Dansie and Turk, 2013). In addition to being highly prevalent, it is extremely costly to the individual with chronic pain, his/her significant others, carers, and to society. The economic burden of chronic pain not only involves traditional healthcare but also causes indirect costs to the country through lost productivity at work, lost tax revenue, legal services, and disability compensation (Dansie and Turk, 2013). Breivik *et al.* (2006) and Azevedo *et al.* (2012) reported that substantial societal economic expenditures are due to chronic pain. Back pain is the most common condition among musculoskeletal problems in older adults, leading to disability. However, along with human costs, this condition is also associated with great health care costs, and acts as a burden to the individual and society as a whole (Docking *et al*., 2011).

Smith and Hillner (2019) stated pain as being extremely expensive and the cost of chronic pain on the governments and societies has been reported to be more than that of cardiovascular diseases and cancer treatment. Gaskin and Richard (2012), as cited by Breivik *et al*. (2013) reported that the total costs associated with chronic pain in the United States exceed those estimated for heart disease, cancer, and diabetes. However, methodological differences limit comparability of financial values associated with each. In Europe, national healthcare and socioeconomic costs of consequences associated with chronic pain represent 3–10% of gross domestic product (Christensen *et al*., 2011; Gaskin and Richard., 2012., and Raftery *et al*., 2012, as cited by Breivik *et al*., 2013). Hospitalisation costs are the largest direct component of chronic pain in adults, making social benefits (disability allowance and unemployment benefits) the biggest single contribution to indirect costs (Neilson, 2013). Despite the soaring cost of treating people with chronic pain, relief for many remains elusive.

Most people with painful conditions continue to experience significant pain that impairs their quality of life, causing significant physical disability and emotional distress (Dansie and Turk, 2013). Satisfactory treatment can only come from comprehensive assessment of the biological aetiology of the pain in conjunction with the patient's specific psychosocial, emotional and behavioural presentation (Dansie and Turk, 2013). Findings from the studies mentioned indicate that very large costs are associated with chronic pain. However, this is even higher in the case of severe chronic pain (Bernfort *et al*., 2015). Although these findings are suggestive of the economic burden of chronic pain, very little is known about health care costs associated with chronic pain in the older adult population specifically. Leave from work due to chronic pain and its consequences is less of an issue for older adults over the age of 65 years since many have already retired from work (Bernfort *et al*., 2015). Therefore, costs including unemployment benefits and sick leave are marginal. However, the costs related to informal care and care performed by municipalities may be significant for this age group due to the increased prevalence of chronic diseases and comorbidities that require other complex health care costs, with greater resource use associated with more severe chronic pain in people aged 65 and over (Bernfort *et al*., 2015).

2.2.5 Models of pain, their history and current developments

Mechanisms underlying pain and the perception of pain have been described by several theories that date back over centuries. Throughout the history of medicine, theories have been proposed to explain why and how individuals feel the pain they feel (Trachsel and Cascella, 2020). Various theories of pain in the early literature include that of Cartesian Dualism, Intensity, Specificity and Pattern theories.

Throughout history, religious ideologies have had a substantial influence on people's thoughts and actions, therefore, the majority of people believed that pain was the consequence of committing immoral acts (Trachsel and Cascella, 2020). Although this concept remained popular up until the nineteenth century, the French philosopher Renee Descartes introduced one of the first scientific theories explaining mechanisms behind pain perception in 1644. This theory of pain by Descartes was among the first scientific philosophy explaining pain occurrence. In the current pain literature, this theory is referred to as the Cartesian dualism theory which hypothesised pain to occur as a result of physical or psychological injury that were mutually exclusive and at no point influenced each other or created any synergistic effect on pain (Trachsel and Cascella, 2020). Descartes theory of pain believed in the traditional philosophy that pain was a simple reflex response to sensory stimuli without any psychological aspect (Waddell, 1987). He also advocated that pain had a connection to the soul and according to his research the soul for pain was in the pineal gland (Chen, 2011), which in-turn meant that the brain was the moderator of painful sensations. He proposed a now famous hypothetical drawing that showed the transmission of pain information via the peripheral nerves and the spinal cord to the ventricles of the brain and the pineal organ where the conscious perception of painful stimuli was supposedly produced (Chen, 2011).

Widespread antipathy towards the dualistic mental philosophy of Renee Descartes in the 'holistic' literature began to appear in the 1970s, and 80s. Pain has always provided a test case for mind-body dualism. The issues of subjectivity and embodiment in relation to pain challenged modern understandings of mind and body. The Cartesian mental philosophy views the body as reduced to mechanistic, organic processes, separated from mental processes, whereas in contrast, contemporary psychosomatic theories of health and illness view mental and biological factors as interdependent (Duncan, 2000). Moreover, dualism theory could not explain why no two chronic pain patients have the same experience with pain even if they had similar injuries. Because this theory had its limitations, it paved the way for further research to overcome its drawbacks. However, it also provided future researchers with a solid foundation to continue expanding the scientific understanding of the intricate phenomenon of pain (Trachsel and Cascella, 2020).

After the 1800s, owing to the development of experimental sciences, the concept of pain gradually began to take form. However, the ideas around pain perception were still being debated due to the complexity of pain and its generator, the brain (Chen, 2011). The argument was whether a specific, hard-wired pathway or a non-specific pathway in the nervous system mediated pain. Four theories were proposed initially; namely specificity theory, intensity theory, pattern theory, and gate control theory (Chen, 2011). Gate control theory has a place amongst the modern-day theories along with the Neuromatrix and Biopsychosocial models of pain (Burmistr, 2018).

The *Intensity* model conceptualised pain as not a unique sensory experience but rather an emotion that occurred when any stimulus became stronger than usual (Moayedi and Davis, 2012). This theory of pain that has been postulated at several different times throughout history suggested that pain occurred in any sensory system when sufficient intensity was reached rather than being a stimulus modality in its own right (Moayedi and Davis, 2012). This theory dates back to the Athenian philosopher *Plato* (*c.* 428 to 347 *B.C.*) who first conceptualised it in the fourth century. The theory defined pain not as a unique experience, but rather an emotion resulting from a long-lasting intense stimulus (Trachsel and Cascella, 2020). Centuries later it was Darwin who reiterated the concept that pain occurred in any sensory system when sufficient intensity was reached rather than being a stimulus modality. Arthur Goldscheider further advanced the intensity theory based on experiments conducted by various scientists during the 1800s.

Since it was the era of experimental sciences, an experiment was conducted on syphilis patients with degenerating dorsal horns (grey matter on the dorsal part of each half of the spinal cord), which revealed that repeated tactile stimulation produced pain. These experiments were then carried out on a number of occasions with different types of stimuli and concluded that some sort of summation occurred through these stimuli to transform sub-threshold stimuli to become unbearably painful. This summation effect, described by Goldscheider, was the neurophysiological reasoning that caused pain to occur (Moayedi and Davis, 2012), a phenomenon that the intensity model used to describe the perception of pain. However, this theory did not believe in stimulus modalities, concepts of nociception, or even specific pain receptors. Hence it lost its support from the landmark discovery of Sherrington's revolutionary framework (described below) of nociception (Moayedi and Davis, 2012).

The *Specificity* model, which came into existence much later than the intensity model believed in the concept of dedicated pain pathways. Initially presented by Charles-Bell in 1811, the theory became well known among the scientists and philosophers who spent the next century developing this theory (Trachsel and Cascella, 2020). According to this theory, each sensory modality has a specific receptor for pain and an associated sensory fiber that is sensitive to one specific stimulus (Moayedi and Davis, 2012). Johannes Muller in the mid-1800s, one of the many contributors to this theory, published in his manual (*Manual of Physiology*) that individual sensations were the result of specific energy experienced at certain skin receptors. He also believed that an infinite number of receptors were present in the skin, which accounted for an individual's ability to discriminate between different sensations. Another significant observation made by Maximillian von Frey towards the end of 1800s was the discovery of four separate somatosensory modalities found throughout the body, which included cold, pain, heat, and touch. This concept correlated with earlier research done on the Specificity model of pain and reiterated the presence of distinct pathways for different sensations (Trachsel and Cascella, 2020).

The landmark discovery by Charles Scott Sherrington on nociception addressing the sensitivity model and its assumptions that different sensory receptors specialised to respond to noxious stimuli existed (Moayedi and Davis, 2012), was further strengthened by the popularity of this model. His further studies also helped resolve the big divide between specificity and intensity theories of pain. His postulated framework supported the specificity theory with specific end points and presence of receptors that are specific to pain and also supported the somatosensory stimulation by intense and excessive stimuli to activate pain reflex (Rey, 1995). However, this theory failed to generate explanations for clinical pain. Further on, it did not explain the mechanisms behind pain sensation owing to factors that were not physical in nature such as emotional or cognitive stimulus (Trachsel and Cascella, 2020). In addition to all these drawbacks, Rey (1995) identified another disadvantage of this theory in that it encouraged ineffective and often counterproductive surgical procedures that destroyed the cells or their axons in an attempt to treat or manage pain. This theory could not provide explanations to the etiology of chronic pain, or even a reason for why pain persisted even long after the healing of the initial injury (Trachsel and Cascella, 2020).

Following the specificity theory, the *Pattern* theory of pain, presented by psychologist John Paul Nafe in 1929, emerged which supported that the spatial and temporal firing profile of the peripheral nerves encoded the stimulus type and intensity; and further on, the intense stimulation of these fibers caused the percept of pain (Moayedi and Davis, 2012). With regards to sensation, the Pattern theory suggested that there were no separate receptors for each of the four sensory modalities, as outlined in the Specificity model, but instead each sensation relayed a specific sequence of signals to the brain to process the pattern. In addition, the afferent fibers respond to a host of stimulus modalities, and that the ultimate perception depends on the brain's deciphering and interpretation of the patterns of activity across the different nerve fibers (Basbaum, 2011). The Pattern theory of pain, suggested that the nerves involved in detecting pain could also detect other sensations. It also rejected the presence of specific nerve fibres or endings used just for the sensation of pain (Chen, 2011). The sensations were supposedly detected by the same nerves, in response to which specific signal patterns were relayed to the brain. The brain then interprets the pattern, including both the sensation and its intensity. Pattern theory gained significant popularity, however, with the discovery of unique receptors for each type of sensation, it became clear that this theory was inaccurate in rejecting the concept of separate receptors for each sensory modality; hence the acceptance and popularity of specificity theory.

The specificity theory was one of the most influential theories of pain in history. Nonetheless, Ronald Melzack and Patrick D. Wall further developed the pattern theory and addressed its shortcomings; supporting the experimental evidence of both specificity and pattern theories to try and bridge the gap between the two most influential theories of the time (Moayedi and Davis, 2012). They developed the Gate-control theory in 1965, which prevailed and directed the development of pain research during the subsequent forty-five years all around the world. The development of the specificity theory waxed and waned before and after the introduction of the gate control theory owing to its limitations and the development of the contemporary evolved Gate-control model for the perception of pain, but even then the specificity theory continued to thrive (Chen, 2011). However, the most contemporary pain models are Gate Control, Neuromatrix, and biopsychosocial theories dominating modern research on pain (Burmistr, 2018).

The first theory to view pain through mind-body interdependence was the Gate Control theory of pain proposed by Melzack and Wall (1965). This theory proposed that pain perception is not simply a sensory process in which the nervous system reacts directly to a harmful contact or substance (Duncan, 2000), but rather a complex experience influenced by cognitive and emotional factors. They rejected the direct line of communication from skin to brain from the Descartes well known illustration of a man with his foot on fire (an example showing the pathway for promptly moving the foot from fire because of the pain sensation felt directly from the fibers of the foot to the spinal cord and then to the brain); and proposed a gate-control model (Duncan, 2000). This model was based on a framework that adapted the experimental evidence of both specificity and pattern theories, based on corroborated physiological data (Moayedi and Davis, 2012) in which peripheral pain signals were modulated by a complex inhibitory feedback system as they pass through the spinal cord and brain stem. This inhibitory feedback system may modify the perception of pain (Duncan, 2000).

Melzack and Wall proposed that the nociceptors synapse in two different regions within the dorsal horn of the spinal cord; they are cells in the substantia gelatinosa and the transmission cells. They proposed that signals produced in primary afferents from stimulation of the skin were transmitted to three regions within the spinal cord: firstly the substantia gelatinosa, secondly to the dorsal column, and lastly to a group of cells that they called transmission cells. They proposed that the gate in the spinal cord is the substantia gelatinosa in the dorsal horn, which modulates the transmission of sensory information from the primary afferent neurons to transmission cells in the spinal cord (Moayedi and Davis, 2012). When pain signals of a certain intensity reach the spinal cord, the gate opens, and these signals are relayed to the brain and pain is felt. This explanation accounted for the physical component of pain. However, this theory also acknowledged the psychological component of pain. In their original study, Melzack and Wall suggested that in addition to the control provided by the substantia gelatinosa, there was an additional control mechanism located in the cortical regions of the brain, apart from the spinal cord. More recently, researchers have indicated that the cortical control centres (prefrontal cortex) in the brain are responsible for the cognitive and emotional factors affecting pain sensations (Trachsel and Cascella, 2020). However, this model could not explain the mechanisms behind pain etiology. Although it has had an overall positive effect in the field of pain research, many of its assumptions relating to the neural architecture of the spinal cord were greatly simplified (Chen, 2011).

Much later in the mid-1900s, Melzack proposed the Neuromatrix model of pain after his exposure to the amputees who were experiencing phantom limb pain in well-healed areas. Most theories (such as the specificity or pattern) until this time implicated that injury of any sort would transmit signals that would lead to pain sensation in the brain. Even though Melzack had contributed to the previous theories, his exposure to these amputees prompted further enquiry into the nature of pain, its etiology and philosophy. According to the Neuromatrix pain philosophy it was the Central Nervous System (CNS) that was responsible for eliciting pain sensations and not the Peripheral Nervous System (Trachsel and Cascella, 2020). The Neuromatrix model states that areas in the CNS (including the spinal cord, brain stem and thalamus, limbic system, insular cortex, somatosensory cortex, motor cortex, and prefrontal cortex) are responsible for signals that allow for the feeling of pain, referred to as neurosignatures. According to this theory, pain is a multidimensional experience produced by characteristic neurosignature patterns of nerve impulses that are generated by a widely distributed network of neurons (body-self neuromatrix) in the brain (Melzack, 2005). Even though sensory inputs may trigger or modify these neurosignature patterns, they may also be generated independent of them. The peripheral inputs could influence these neurosignatures as in the case of acute pain evoked by brief noxious inputs. Even the non-physical pain factors (such as psychological stress, little or no injury or pathology in chronic pain syndrome conditions) are explained through the neuromatrix pain model (Melzack, 2005).

Melzack’s theory claimed that there were specific neural patterns for these non-physical pain factors as well that elicited pain sensations, and if there occurred alterations in a certain signal, it allowed for memory formation of these particular experiences. Additionally, if these similar non-physical factors generated neurosignatures on a different occasion, it would allow for a similar pain sensation

(Trachsel and Cascella, 2020). It proposed that the output patterns of the body-self neuromatrix activate perceptual, homeostatic, and behavioural programmes after injury, pathology, or chronic stress; thereby producing pain through widely distributed neural networks in the brain rather than just by sensory inputs evoked by injury. It therefore extended the Gate Control theory from physical, cognitive and emotional factors eliciting pain sensations only, to memory and behaviour patterns after injury also playing a role in pain sensations. It thus provided a conceptual framework and understanding for various chronic pain conditions, something that was poorly understood before this model (Burmistr, 2018). However, even this multidimensional understanding of a pain model failed to account for social constructs that influences pain (Trachsel and Cascella, 2020).

During the 1980s, the biopsychosocial model of pain arose in response to the Gate-Control theory; it not only addressed the psychological aspect of pain but also the social construct of an individual in pain that neither the Gate-control nor Neuromatrix models accounted for. Furthermore, the earlier theories such as Specificity, Pattern or Gate-control did not respond to medicines' inability to treat chronic pain and to control pain-related disability. Although acute pain was controlled through organic interventions through concepts laid down by these theories, chronic pain presented an obstacle. Moreover, the disability associated with chronic pain could not be entirely attributed to bodily impairments and pathology. Psychological and behavioural responses to pain were seen as integral parts of the problem, such as coping strategies, attention/avoidance of pain, emotional regulation of pain, pain related fear, and cognitive response to pain (Linton and Shaw, 2011). These types of psychological processes are highly intertwined and function as a system contributing to the development of persistent pain problems (Linton and Shaw, 2011). Hence any theory explaining the chronic pain mechanism must include, along with the others (such as pathology, physical/non-physical injury, stress), psychological processes and cultural and social contexts of the individual in pain (Duncan, 2000; Linton and Shaw, 2011; Lumley *et al.*, 2012).

More recently, researchers and pain scientists deemed it necessary to broaden the definition of pain beyond bio-medical parameters by including a psychological dimension (Trachsel and Cascella, 2020). The contemporary definition of pain used by the IASP is based on the multidimensional definition proposed by Melzack and

Casey that include the sensory-discriminative (intensity, location, quality, and duration), the affective-motivational (unpleasantness and the subsequent flight response), and the cognitive-evaluative (appraisal, cultural values, context, and cognitive state) dimensions of pain. These three dimensions interact with one another and are not independent. However, they are partially dissociable; the cognitive state of a person can modulate one or both of these dimensions of pain perception (Moayedi and Davis, 2012).

This biopsychosocial theory hypothesises pain as a result of a complex interaction between biological, psychological and sociological factors and proposes a comprehensive framework for the management of pain. The biopsychosocial model was first proposed by anesthesiologist John D. Loeser, who developed and utilised this model in relation to pain (Trachsel and Cascella, 2020). His model broadens the definition of pain ranging from raw sensations to higher-order perception, which as a result enables scientists to account for the role played by emotion and learning processes of the brain on pain experience and related behaviours. It clearly makes a distinction between the neural signal (nociception) and the complexity of emotions and behaviours, which may or may not follow from nociception. This is true especially in cases of chronic pain where there may be little correlation between nociception and pain perception and behaviour. Nociception usually leads to pain, which is defined as a perceived noxious input to the nervous system. This link between nociception and pain is moderated through surgical, pharmacological, or psychological measures; which points to nociception as a peripheral event whereas pain is a feature of the spinal cord and brain. Furthermore, just like there is nociception in the absence of pain, there is pain even without nociception (Duncan, 2000).

Pain theories and models over time have formed the basis for the development of pain management techniques ranging from pharmacological/analgesic means, institutional pain fighting measures (efficiency of pain management and analgesic regimes) to more evolving methods that require biopsychosocial, multidimensional and an interdisciplinary approach. However, it is important to first classify pain by means of a comprehensive and efficient assessment so that it can be appropriately diagnosed before deciding its management and treatment. The following section will explore the measures to evaluate, classify and diagnose chronic pain through standardised assessment tools.

2.2.6 Chronic pain measures

Accurate pain assessment is important when classifying or diagnosing chronic pain experiences in different patients (Fillingham *et al*., 2016). Pain assessment helps to evaluate the severity of the condition, guides the treatment plan, and allows both the clinicians as well as researchers to monitor the longitudinal course of pain, which in-turn measures treatment effects and target interventions (Fillingham *et al*., 2016; Reid *et al*., 2015). However, chronic pain is multidimensional in nature, therefore, for an efficient assessment it requires a comprehensive multi-axial approach. Such an approach is inevitable and allows for an effective treatment and management plan (Dansie and Turk, 2013). Appropriate measurement tools are required to assess clinical pain domains and its underlying mechanisms. Since chronic pain is an internal experience, the gold standard method for its measurement remains self-reported (Fillingham *et al*., 2016). Therefore, pain assessment has a subjective component and so the instruments used to measure pain are questionnaires or indices. These instruments have been created in an attempt to make the follow-up of patients with pain uniform and to quantify pain intensity, pain related interference, and pain impact on the quality of life (Martinez *et al*., 2011).

An essential point to note here is that, multiple factors influence the symptoms and functional limitations of individuals with chronic pain. Thus, such a comprehensive assessment is desirable that addresses biomedical, psychosocial, and behavioural domains, as each contributes to chronic pain and its related disability (Turk and Rudy., 1987, as cited by Dansie and Turk., 2013). However, when only pain intensity is measured in a clinical setting (acute pain experience), a unidirectional instrument such as the Visual Analogue Scale (VAS) works well. But in the case of chronic pain where multiple underlying factors need attention and a comprehensive assessment is needed, a multidimensional instrument is required (Martinez *et al*., 2011).

Administering standardised multidimensional pain assessment instruments provides additional information beyond what is generated from an interview, clinical history and physical examination (Reid *et al*., 2015). Some of the tools used to measure chronic pain experience in older adults (Reid *et al*., 2015) are the Brief Pain Inventory (BPI), and the Geriatric Pain Measure (GPM). These are recommended for routine use in practice because they are easy to complete, have been successfully used in studies of older adults, and assess multiple salient dimensions (such as pain intensity, pain related interference, and pain related disengagement) of the pain experience. Older patients can employ this assessment without much difficulty and it can be used at subsequent visits with ease to assess change in a given outcome over time. The GPM has shown significant validity and reliability in older people with multiple health issues (Ferrell *et al*., 2000) and is useful in the clinical assessment process and management of pain, and in pain-related research in older persons (Blozik *et al*., 2007). Dansie and Turk (2013) used the Brief Pain Inventory (BPI) scales (Cleeland, 1989) as a standard tool to measure chronic pain intensity/severity and interference with daily activities. These have also been used in studies on older adults (Reid *et al*., 2015).

In summary, there are various standardised assessment tools that can be utilised for a comprehensive pain assessment that capture various domains of chronic pain. The various domains include pain intensity, pain interference with daily activities, emotional distress (depression and anxiety), and overt expressions of pain (Dansie and Turk, 2013). Measures that capture pain intensity are the numerical rating scale (NRS), the verbal rating scale (VRS), the McGill Pain Questionnaire (MPQ) (Melzack, 1975), and the brief pain inventory (BPI) subscale for severity. The measures to capture pain interference are the pain disability index (PDI), the brief pain inventory (BPI) subscale for interference, and the functional independence measure. For measuring emotional distress, tools that can be used are the Beck Depression Index (BDI), and the Profile of Mood Scales (POMS). The tools that can be used for assessing overt pain expressions are through verbal pain expression (self-report), and non-verbal pain expression (displaying of pain behaviour) (Dansie and Turk, 2013).

The assessment of chronic pain can also be achieved by classifying the different domains of pain as sensory and affective qualities of pain, temporal characteristics of pain and others, such as pain location and pain behaviour (Fillingham *et al*., 2016). According to Fillingham *et al*. (2016), measures such as NRS and BPI can be used to assess pain intensity; and for pain affect, MPQ and NRS can be used. The temporal characteristics (duration, variability, modifying factors) of pain can be assessed by retrospective self-report. Other measures include the identification of pain location by pain drawing and pain behaviour by facial expressions (Fillingham *et al*., 2016).

BPI and MPQ are considered to be comprehensive questionnaires providing a detailed assessment of chronic pain (Martinez *et al*., 2011). However, the authors of this study found that the BPI scale was preferred over the MPQ as it assessed major clinical characteristics of pain and its impact on daily functions. Elements of the BPI involve items that are usually used in medical consultations for diagnosis and follow-up; thus, physicians and patients prefer it. The authors argued that the MPQ has a list of pain descriptors that is qualitative in nature but used to provide quantitative indices, which can be used for scientific studies. Therefore, both these multidimensional instruments have advantages for assessing chronic pain in its complexity, but both also have some limitations such as being time consuming and using lengthy questionnaires that can be particularly difficult to administer to very ill patients.

The McGill Pain Questionnaire (MPQ) and its brief analogue, the short-form MPQ, are among the most widely used measures of pain. MPQ is considered as a multidimensional instrument to measure pain quality. However, it also yields numerical indices of several dimensions of the pain experience. The MPQ comprises of 20-sets of descriptors that assess sensory (10), affective (5), evaluative (1) and miscellaneous (4) aspects of pain. In addition, it consists of a measure, present pain intensity (PP1), ordered from mild to excruciating (Melzack, 1975).

The findings from studies in the literature suggest that a comprehensive detailed measure to assess pain is crucial given it is a subjective and complex phenomenon. The most commonly preferred pain instruments used by the studies are the MPQ, BPI, GPM, and the NRS. Of these the BPI subscale will be discussed in more detail in the relevant methodology section (chapter five), since it was the scale used for measuring pain outcomes by the MBS and the current study.

2.3 Review of the literature on pain epidemiology in older adults

There appears to be a potential for an ageing pain "time bomb" (Kumar and Allcock, 2008). Epidemiological surveys have suggested that pain prevalence grows with increasing age, with women being more likely to report pain than men (Tsang *et al*., 2008). Older adults undoubtedly have always been at a greater risk of pain (Reyes-Gibby *et al*., 2002), which can lead to a poor health related quality of life. Musculoskeletal pain is common in older adults and is associated with disability and health-care costs, with back pain being the most prevalent regional condition among all (Docking *et al*., 2011). Docking et al., (2011) reported that an increase in disabling back pain increases with older age in contrast to non-disabling back pain. Generally, poor health is a known predictor of back pain, as health status tends to decline with age, therefore the older population may be at even greater risk (Docking *et al*., 2011). Chronic pain and its negative consequences are particularly significant amongst older adults because many of them lose their independence and require help with daily living. Since chronic pain is associated strongly with an increase in age, it is important to identify the factors contributing to the development and progression of it among older adults. This in turn is significant for managing chronic pain and its associated disabilities (Leung *et al*., 2015).

Older adults also suffer from multisite or generalised chronic pain conditions. People with pain that is widespread throughout the body have worse health outcomes compared to those with less diffuse pain or those who are pain free (WHO, 2003). Widespread pain has also been associated with a number of independent predictors such as female sex, cognitive impairment, financial strain, education, and prior experience of pain (McBeth *et al*., 2014). In older people, widespread pain is common and is strongly associated with poor outcomes across multiple health domains, and older persons who suffer from pain in multiple sites are more vulnerable with greater functional consequences (Leveille *et al.,* 2009).

Chronic pain is associated with a number of negative factors such as depression, reduced quality of life, impairment of function, job loss, and has a significant impact on people's lives (Bair *et al*., 2003, Breivik *et al*., 2006). There is also a possibility of greater disability risk owing to central mechanisms whereby cognitive effects as a result of chronic pain interfere with mobility. This pain experience in older adults is associated with executive function deficits. For example, suboptimal memory performance, perceptiveness, reasoning, intelligence, and cognitive speed are associated with a lack of mobility, falls, and functional dependence (Leveille *et al.,* 2009).

It has been suggested that older people are the most susceptible age group to experience pain (Kumar and Allcock, 2008; Docking *et al*., 2011). It is, however, challenging to establish the characteristics of pain and its population prevalence since the issue of pain is complex in older adults. This complexity is due to difficulties in defining pain measures in this population, asking the right questions to quantify their pain, or conducting studies that best explore and comprehend the subject of chronic pain in older adults. It is even more difficult to ascertain comparisons across studies largely owing to differences in pain assessment and the pain measures used. This problem is amplified by the fact that most prevalence studies do not incorporate a sufficiently large number of questions required to explain an individual's pain experience effectively (Helme and Gibson, 2001). All the more, in older adults the self-reported pain prevalence is lower in those who have impaired cognitive function since they suffer from memory loss and so they often overlook or forget to report pain, when compared to those who are cognitively intact (Parmelee *et al*., 1993, Proctor and Hirdes, 2001). Therefore, establishing the population prevalence is not only challenging but also sometimes impossible.

2.3.1 Review of studies on pain prevalence

The studies on pain prevalence in older adults report a wide range of themes ranging from pain distribution, onset and prevalence, type of pain outcome (severity and interference with daily activities), pain location, and chronic pain related health consequences. The following studies described provide information on an adult sample of middle to older ages, which includes people of ≥65 years. Most studies on chronic pain in older adults focus on the recent onset of pain. This emphasis on recent pain in the last month could be owing to cognitive impairment and memory function deficits in this population. Inaccuracy of patient's memory in recalling past pain episodes has been proposed as a potential barrier in assessing temporal features of pain (Fillingham *et al*., 2016). Although many of the studies identified pain present in the last four weeks (Thomas *et al*., 2004; Brown *et al*., 2011; Docking *et al*., 2011; Shega *et al*., 2012; Wilkie *et al*., 2013; Docking *et al*., 2014; McBeth *et al*., 2014), there were some studies that identified pain in the last three months (Jakobsson *et al*., 2003; McCarthy *et al*., 2009). These studies, however, explored many of the same aspects of pain and its associated characteristics in older adults, and demonstrated some similarity in their results.

Widespread Pain distribution: It was noted that a number of studies reported the occurrence of widespread pain in older adults. The definition for widespread pain in these studies was derived from the American College of Rheumatology (ACR) criteria 1990 for fibromyalgia, where pain needed to be present in the left and right side of the body, both above and below the waist and in the axial skeleton. The widespread pain prevalence was 12.5% among older adults aged ≥50 years as reported by Thomas *et al.* (2004). However, this study was more stringent in its criteria for widespread pain, where axial pain plus pain in at least two sections of each of the two contralateral quadrants of the body, was required to be present. This study also reported higher female prevalence when compared to males.

Wilkie *et al.* (2013) conducted a study over a period of six years; and reported that the widespread pain onset at three years follow up was 16.8% and at six years follow up was 14.3%. Women were more likely to report widespread pain when compared to men. The study concluded that when widespread pain increased, the markers of unhealthy ageing increased as well (Wilkie *et al.*, 2013). Docking *et al.* (2014) reported in their study on the epidemiology of regional and widespread pain that chronic widespread pain (CWP) increased more in rural than in urban older adults aged ≥55 years. It was reported as 17% in urban locations compared to 22% in rural locations. Female gender was significantly associated with chronic widespread pain in this study. Factors independently associated with CWP in this study were poor general health, feeling low and female gender. Previous pain was a predictor for new pain onset as demonstrated by the study on predictors of widespread pain in older adults by McBeth *et al.* (2014). They reported new onset widespread pain among their follow-up participants who were pain free at baseline (18.5%). However, from among those who had some pain at baseline, 24.6% reported new onset widespread pain. Therefore, having some pain was associated with higher rates of pain prevalence among this population of older adults. Another finding was that women were more likely to report widespread pain than men at follow up.

In summary, the findings from these studies indicate that widespread pain is associated with increasing age both from cross-sectional (Thomas *et al.*, 2004) and longitudinal (Wilkie *et al.*, 2013; McBeth *et al.*, 2014) study designs. The findings were also suggestive of widespread pain affecting both rural and urban older populations. All the studies described above reported that prevalence of widespread pain was higher in females than in males. This could be due to females suffering more from chronic pain than males or possibly because they are more likely to report pain than males. In either case, the influence of the psychological threshold and the social construct they live in, points towards the role of psychosocial factors.

Pain onset and prevalence: In a study on the prevalence of self-reported pain, its occurrence, location and interference with daily activities, Thomas *et al.*, (2004) reported the prevalence of any pain in the last four weeks as 72.4% and that of widespread pain as 12.5%. Pain was self-assessed through the self-risk appraisal questionnaire in a study by Carmaciu *et al.* (2007) and those who were identified as having felt any pain in the last four weeks (45% women and 34% men), completed the Geriatric Pain Measure scale to explain their pain experience and its impact on daily living. This study reported that the prevalence of pain increased until the age of 84 but then decreased in the oldest adults (>84years). McCarthy *et al.* (2009) conducted a study on an adult population aged ≥70 years to determine the prevalence of chronic pain. The overall prevalence rate was reported as 52%, although higher in females (58.9%) than in males (39.7%).

Baek *et al.* (2010) tried to find the prevalence of musculoskeletal (MSK) pain in an older adult Korean population ≥65 years of age. The age and gender standardised MSK pain prevalence for upper extremity, lower back and lower extremity was 62.6%, 72.6% and 45.7% respectively. The study concluded that MSK pain was a significant problem of the older adult population, with lower extremity pain being most prevalent with increasing age. Pereira *et al.* (2014) in their study on pain prevalence and intensity, on a population sample of older adults, reported 52.8% prevalence for overall pain. In another study, Fransen *et al.* (2014) investigated the burden of chronic knee pain in a sample population of older adults (≥70 years) over a period of two years. At baseline, around 40% reported knee pain. Of those 60% who had no pain at baseline, 81% reported back on follow up. From among the follow up population, 20% had new onset knee pain. Similarly, Rottenberg *et al.* (2015) explored the epidemiology of chronic pain in older adults ≥70 years and found that visceral pain (headache and abdominal) disappears with age. However, pain such as chronic neck/back or chronic joint pain remained prevalent in older adults. Overall, pain prevalence at age 70 was 73% but this prevalence decreased in older adults, aged 75+. Pain was associated with female gender but only for the older adults who were at the youngest end of the scale. Yet again the female gender was associated with higher pain prevalence.

The overall results of these studies might suggest an increase over time in pain prevalence among the older adult population. For example, the prevalence figure reported by Thomas *et al*. (2004) was 12.5%, but a study on a similar age range of older adults ten years later reported a prevalence figure of 22% (Docking *et al.,* 2014). It might be the case that the sample in the Docking *et al*. (2014) study had a larger number of participants exposed to pain than the earlier study or had measures that captured a lower threshold of pain and higher specificity and sensitivity to pain outcomes. Therefore, there is a need to conduct longitudinal studies with the same sample in order to reliably determine if there is an increase in pain prevalence. It is also possible that instead of the prevalence of pain actually rising for older people, there is an increased health awareness among older adults that leads to a greater reporting of pain, or a change in their willingness to report pain. Although, an increase in pain prevalence in more recent years is seemingly apparent from these studies, to estimate a true increase, only a longitudinal study design using the same measures to assess pain each year could provide a more reliable indicator.

In summary, in almost all of the studies that explored chronic pain in older adults, females were more likely to report higher pain prevalence than males. However, this was not the case for very old adults. Pain prevalence increased with increasing age. However, it did not increase in very old older adults (75 years and older, and 84 years and older). While the prevalence of pain is greater in older adults compared to younger adults, it is still not clear whether the proportion of older adults reporting pain has increased over time.

Pain severity: A study by Docking *et al.* (2011) on prevalence and risk factors for back pain onset found from their sample population of 1174, that, 6% reported disabling and 23% reported non-disabling back pain. There was also a considerable difference in the onset of both disabling back pain prevalence between men (3%) and women (7%), and non-disabling back pain onset between men (17%) and women (26%). It was noted that the prevalence of disabling back pain increased with an increase in age. In another study, Brown *et al.* (2011) reported that 41% of their sample of older people had disabling pain, with musculoskeletal pain being the most predominant condition among its older adults. This draws attention to the severity of the problem and actions required including early assessment and treatment.

There were some studies that explored disabling and severe pain in older people and concluded that disabling pain increased with increasing age and this again was higher in females than males. Such disabling pain were present in multi-site predominantly weight bearing areas (the lower extremities) and caused functional limitations in the older adults.

Pain interference: Chronic pain in community dwelling older adults can lead to immobility (Reyes-Gibby *et al*., 2002). The sample population in the study by Thomas *et al*. (2004) were initially asked if pain often bothered them, and at 12 months follow up the sample population was asked if pain kept them from doing things they wanted to. The results showed that 33% were often bothered with pain at baseline, and 20% had significant pain resulting in activity limitation at follow up. Females (37%) had a higher prevalence of pain than males (28%). The pain that increased with the activities of daily life (pain interference) demonstrated an incremental rise with age (Thomas *et al*., 2004). Furthermore, lower limb (hip and knee) pain interfered with few specific activities of daily living also known as ADLs (Cechi *et al*. 2009). However, those with hip pain were significantly more likely to need help with tasks such as shopping, using public transportation, cutting toenails etc. Chronic knee pain has also been significantly associated with mobility disability (Fransen *et al*., 2014)).

Pain location: A decline in most regional pain types was reported, with the exception of lower limb (hip, knee, foot) pain, in the study by Thomas *et al*. (2004). The study by Cechi *et al.* (2009) found that both hip pain and knee pain were associated with disability and musculoskeletal impairment and ascertained that lower extremity joint pain is reported as a strong determinant of functional immobility in older adults. Baek *et al*. (2010) reported that lower extremity pain increased with age, whereas the others did not. Fransen *et al*. (2014) reported an increase in chronic knee (lower limb) pain with increasing age. Among those who reported pain in the Pereira *et al*. (2014) study, 49.6% reported it in a single site and 15.1% in more than three sites. The highest prevalence of pain was in the lower limbs (34.5%), followed by the lower back (29.5%). Females were 2.3 times more likely to present pain than males.

These studies on pain interference and pain location indicate that pain can lead to interference with daily activities, and functional immobility can increase with age. This type of pain, in particular, affected older adults' lower limb areas such as knees, hips and lower back. Lower limb pain is also shown to increase in older adults. This could be a reason why pain interference increases, in turn increasing mobility difficulty with age. This is due to most activities of daily living requiring functional independence, and mobility needing knees, hips and the lower back to be strong and pain free.

Chronic pain consequences: Chronic pain in older adults not only leads to physical health problems, but also affects social and mental wellbeing (Cechi *et al*., 2009; Reyes-Gibby *et al*., 2002; Shega *et al*., 2012; McCarthy *et al*., 2009). Shega *et al.* (2012) found an independent association of pain with social vulnerability. The authors defined the index of social vulnerability as a collection of various self-reported variables that characterised a person's social circumstance including the ability to engage in the wider community, their living situation, social support and ability to maintain social ties and engagement, sense of control over one's life and one's socioeconomic status. This was an important finding as it is also suggested that there is a 5% increase in mortality for each increase in the social vulnerability score. Therefore, this makes social vulnerability and isolation a critical aspect of an older adult's life. Furthermore, in a study on the onset of widespread pain and its association with a decrease in healthy ageing, Wilkie *et al.* (2013) reported that the markers of unhealthy ageing increased with the self-reported onset of widespread pain over a follow up period of six years. Healthy ageing in this study was characterised by functional independence, physical and psychosocial health enabling cognitive, mental, physical wellbeing, social participation and improved quality of life. The study concluded that when widespread pain increased, the markers of unhealthy ageing increased as well (Wilkie *et al*., 2013).

Findings from these studies demonstrate that chronic pain leads to debilitating consequences on healthy ageing, social and mental well-being, and improved quality of life. Social vulnerability owing to chronic pain experience predicted mortality in older adults. These are important findings for clinicians in terms of assisting with better assessment of pain and encouraging the adoption of an interdisciplinary approach to manage pain and its consequences among older adults.

Overall findings: It appears that pain is predominately measured via self-report, but the definition of pain varied across studies. However, there are a large number of studies that recorded pain prevalence in the last four weeks. Asking about recent pain prevalence works best for older adults, as they are more prone to memory loss and cognitive impairment, although this might lead to an under estimation of the problem of pain since those older adults who are cognitively impaired or have had pain experiences further in the past will not be recorded. Problematically, these older adults often did not make it to the final sample and are therefore not included in the analysis.

Pain in older adults is widespread and mostly affects the lower extremities making it a reason for mobility difficulty. This pain is disabling, severe and also affects healthy ageing as suggested by the studies described in the literature. Chronic pain in older adults does not just occur alone, but many times leads to problems such as depression and social vulnerability; and even isolation owing to functional disability. This calls for greater attention and strategies of care from a public health perspective, but also requires more research on the subject of pain. Better understanding of the risk of pain, and protective factors of pain, will help improve the management and treatment of pain.

There is a need for more research on pain in older people that employs standardised measures based on pain definitions or defining other associated factors with it. In addition, there is a need for more longitudinal studies to determine genuine increases in the prevalence rates of pain over time. This will allow developmental trends of pain prevalence to be more accurately documented and make the identification of predictors of changes in pain prevalence possible. The burden of chronic pain is high, and the accompanying health outcomes are substantial. As such, more research to better understand the management of chronic pain will have health and economic benefits. This study will aim to add to the kneolwdge base on pain by further understanding changes in pain severity and pain interference over an 18-month period, as well as explore the potential effects of social networks and social activity on the experience of pain.

2.3.2 Review of studies on pain risk factors

Studies on pain among older adults have tried to explore the potential risk factors involved in the onset or progression of pain. Various risk factors associated with pain outcomes are recognised among older people, including having depression, being female, having a lower income and lower quality of life, cognitive impairment, disability, and prior experience of pain (Baek *et al*., 2010; Carmaciu *et al*., 2007; Jakobsson *et al*., 2003; McCarthy *et al*., 2009)

Depression and lower quality of life: Depression and a lower quality of life are more prevalent in older adults with chronic pain (Jakobsson *et al*., 2003). A significant association has been identified between depressed mood and pain experience (Carmaciu *et al*., 2007). However, the majority of participants reporting pain were not diagnosed with clinical depression. Chronic pain sufferers are 2.5 times more likely to be diagnosed with depression (McCarthy *et al*., 2009), and depressive symptoms can be a potential risk factor for MSK pain (Baek *et al*., 2010). There is also evidence of a dose-risk relationship when examining self-rated health as a risk factor for back pain onset. Docking *et al*. (2011) found that those reporting poor self-rated health at baseline had a fourfold increased risk of reporting back pain onset at follow-up compared to those who had reported very good health at baseline. Participants who were severely depressed had a twofold-increased risk of onset of back pain as compared to those who were not depressed. Anxiety, depression and lowered health related quality of life and disturbed sleep were found to be possible determinants of having new onset of widespread pain in community dwelling older adults. However, the factors that were independently associated with new onset widespread pain among older adults in multivariate analysis were impaired sleep (odds ratio = 1.2), anxiety (odds ratio = 1.5), and poorer HRQoL (odds ratio = 1.3). Docking *et al*. (2014) in their cross-sectional study concluded that the risk factors that came to be independently associated on multivariable analysis with chronic widespread pain in this population were poor self-rated health (RR=3.5) and feeling low (RR=1.54).

Female gender: Women are more likely to report new onset pain at follow up (over three years) than men (e.g., McBeth *et al*., 2014), and being female has a greater association with chronic widespread pain (Docking *et al*., 2014).

Lower income or education: Participants who were uneducated or had a lower level of education (odds ratio = 2.26-4.09) and lower income (odds ratio = 1.7-2.3), reported MSK pain (Baek *et al.*, 2010). Pain was highest in those who did not continue into higher education, were outside the healthy BMI range, and were under financial strain (McBeth *et al.*, 2014).

Cognitive impairment: Cognitive impairment (odds ratio = 1.3) was found to be an independent indicator of new onset widespread pain in community dwelling older adults (McBeth *et al.*, 2014).

Disability: Pain risk factors were explored in a study by Jakobsson *et al.* (2003) which demonstrated that problems with walking (odds ratio = 2.3-2.9), mobility (odds ratio = 1.7-2.2), and sleeping (odds ratio = 1.6-1.8) were more common in participants who reported pain than those who were pain free.

Prior pain experience: Carmaciu *et al.* (2007) reported that participants who presented with arthritis were four times more likely to be in pain. Participants who reported having disabling back pain before baseline had a twofold increased risk of back pain onset as compared to those who had no such complaint at baseline. Disabling back pain was defined as back pain that interfered with daily tasks within the past month (Docking *et al.,* 2011). To identify the possible determinants of having a new onset of widespread pain in community dwelling older adults, McBeth *et al.*, (2014) found that widespread pain was reported more at a three year follow up in those who had some pain at baseline (24.6%) compared to those who were pain free at baseline (7.7%). Therefore, they concluded that some pain at baseline to be an indicator for new onset widespread pain in their sample population.

Others: Measures of social contact were associated with back pain onset (Docking *et al.*, 2011); lesser social participation is found to be associated with new onset of widespread pain (McBeth *et al.*, 2014). Docking *et al.* (2014) demonstrated that those who had fewer people to ask for help in crisis situations were more likely to report CWP. This finding of having fewer people to turn to in a crisis being significantly associated with CWP was consistent with the wider literature on social support and contact.

Overall findings: The above-mentioned studies and their findings on pain risk factors and its association with pain outcomes in older adults indicates that pain is a complex issue. Factors such as age and female gender are associated with chronic pain, and socio-economic variables such as lower income, lower education and economic status are associated with higher pain prevalence rates. The health variables that are associated with pain in older people include depression, cognitive impairment, sleep deficiency, functional immobility, disability and lower self-rated health. Previous disabling pain, underlying pain conditions such as osteoarthritis and arthritis were also found to be risk indicators of new onset pain. Pain also adversely affects health-related quality of life and is the cause of functional immobility.

The risk of functional limitation (difficulty in walking or mobility) could lead to social isolation, and potentially result in an increase in depression and loneliness. These study findings inform the selection of key factors to include as covariates in this study due to their potential to affect the relationship between social networks/activity and pain outcomes.

2.4 Social networks & health in older adults

The third and last past of this chapter focuses on social networks and its protective role on the health and wellbeing of older adults. It first explores the history of social networks, and the network models established by early authors. It then provides definitions of social networks as they developed in the literature. Lastly, it explores the protective role of social networks on various health outcomes.

2.4.1 History of social networks and the development of the network models

In the 1980's social networks became the focus of considerable attention in health research, particularly for their protective role (Seeman & Berkman, 1988). Much of the early research on social networks and health involved secondary analyses of existing data (Cassel, 1976; Kaplan *et al.*, 1977; Blazer, 1982; Berkman, 1986 as cited by Seeman & Berkman, 1988). These were mostly crude measures of social ties with spouse, children, relatives or marital status and ties with friends (Seeman & Berkman, 1988; Glass *et al.*, 1997), therefore much of the earlier epidemiological research treated social networks as one-dimensional (Glass *et al.*, 1997). These studies addressed the suppositions that social ties were associated with better health outcomes owing to the support they provided to an individual. Most of the studies then assumed that social network ties represented sources of support (Seeman & Berkman, 1988). However, earlier research clearly identified social network ties as sources of conflict, demand and strain (Croog, 1970; Wellman, 1981; Wellman, 1985 as cited by Seeman & Berkman, 1988). This was especially identified in the case of older adults since their closest contacts, such as partner, spouse or friends, could be themselves experiencing disability and in need of support (Seeman & Berkman, 1988). Thus, for successful social network interventions, protective social ties and network characteristics that provided adequacy of support in older adults needed to be identified (Seeman & Berkman, 1988). This was deemed as crucial owing to the growing burden of disease and disability associated with older age. Despite evidence on social ties being protective (Seeman & Berkman, 1988), as well as a source of strain (Wellman, 1981; Wellman, 1985), relatively little was known about components of social networks that were most crucial or by what set of mechanisms they were protective (Glass *et a*l., 1997).

There were repeated calls for more refined, sophisticated and theoretically informed approaches to measuring social networks (Berkman, 1986). Despite these appeals to integrate more sophisticated measures of social networks and extensive research in the area of social networks and health, little was done to conceptualise social networks, and less was known about the elements that made it protective (Glass *et al.*, 1997). Research has suggested that social networks are a multi-dimensional concept (Argyle, 1992, Thomas *et al.,* 1985), especially in the case of older adults, where it is a much more complex issue (Wellman & Hall, 1986). It is the influence of functional status and its variations that further create complexities in the measurement of social networks (Minkler, 1985). Therefore, Glass *et al.* (1997) excluded such network indicators, which were most likely to be confounded by health and physical functioning, such as participation in group activities or church activities. According to the authors, epidemiological research had been treating social networks as a unidirectional concept only. Researchers were not making use of empirical research done previously to measure both the nature and characteristics of social networks. Addressing this issue Glass *et al.* (1997) proposed a measurement model to describe and define the interrelationships between the subdivisions and multi dimensions of social networks using data on older adults from a community-based study. It was envisioned that such an approach would be able to explore the impact of social networks on health outcomes in future longitudinal studies. In their network model, they included indicators both of the existence of ties (including the number of ties, and the proximity of contacts) and also the functional consequences of those ties including frequency of visual contacts, and reciprocity in the provision of support. Glass *et al.* (1997) based their approach on two basic network models, namely, structural (such as network or social support), and role specificity or functional (such as type of social relationship). In other words, a new set of network measures and a network model were demonstrated through this study for use in future health epidemiological studies on older adults. A study by Bassuk *et al.* (1999), examined both structural and qualitative aspects of social networks in relation to cognitive ageing. The social disengagement index was produced through a comprehensive assessment of social connections and activities completed during in-home interviews (described below under social network measures). The authors examined levels of social engagement and support as predictors of risk for cognitive impairment in the Yale Health and Aging Study, a longitudinal, population-based cohort study of older adults. The results over a 12-year follow up indicated that greater baseline social engagement was shown to be protective against cognitive impairment.

More recently, a range of causal processes has been proposed by Berkman *et al.* (2000) to demonstrate the connection by which social relationships influence health. Processes ranging from macro-social (cultural, economic and environmental) to psychobiological (access to material resources and behavioural factors) propose an existence of a causal connection between social networks and health outcomes both mediated by upstream and downstream factors. Berkman *et al.* (2000) have defined social networks based on their structure (number of ties, proximity of relationship), and function (frequency of contact, reciprocity), which has similarities with the network model demonstrated by Glass *et al.* (1997). Based on the nature or specific role of a relationship (friend, relative, children, spouse), networks can be further divided into sub networks. Networks generate support, which might be a mediating factor between the network's ties and health (Berkman *et al.,* 2000). A network's effect on health depends totally or partially on the ability of the network to provide support.

Berkman *et al*. (2000) also included engagement in social activities as an important factor influencing health outcomes in older adults in their conceptual model on social networks. Social activity effects on health may be mediated by psychological mechanisms: being involved in the community may boost positive feelings about self, feelings of mastery and coherence. The model by Berkman *et al*. (2000) and its theoretical framework will be discussed in detail in the next chapter (chapter 3).

2.4.2 Social network definitions and measures

Seeman and Berkman (1988) defined social networks based on network structure and network support. Network structure was formed of the size of a network (ties with children, relatives, and friends). Network support was in the form of emotional and instrumental. Glass *et al*. (1997) aimed to develop a network model and provide a new set of social network measures for epidemiological research in older adults. They defined social networks based on two approaches: indicators of network structure, and indicators for role-specificity (function) of networks.

Social engagement has been defined as the maintenance of many social connections, and a high level of participation in social activities (Bassuk *et al*., 1999). Their study on effects of social disengagement on cognitive decline in the older population included both social network and social activity measures to predict health outcomes in their study. Social networks have been defined as the web of social relationships that surround an individual and the characteristics of those ties (e.g., Mitchelle, 1969; Laumann, 1973; Fischer, 1982, as cited by Berkman *et al*., 2000). Based on the concepts proposed by Berkman *et al*. (2000), the social network is the tissue of social relations that the individual has, and is related to health outcomes through a variety of psychosocial mechanisms (Escobar-Bravo *et al*., 2012), such as emotional and instrumental social support, social influence between the actors of the network, participation and social commitment, and person to person contact access to material resources. All of these definitions include both social network (structure and function) and engagement in social activities to define a network relationship as a whole. In line with definitions and concepts proposed by Berkman *et al*. (2000), social networks have also been defined as the social structure that provides connection and potential support (Stephens *et al*., 2011). Although an individual might perceive a lack of support despite a presence of a large network, the presence of an actual social contact is still required to provide any sense of support or lack of it (Stephens *et al*., 2011).

Social isolation is defined as the inadequacy or dearth of regular social contacts and relationships with relatives, friends and neighbours. It involves a lack of social connection and involvement with the wider society (Singer, 2018). This scarcity of social contact within an individual's network can be objectively measured. Measures of social isolation typically include evaluations of the size of one's social network, number of interactions with family members, friends and neighbours and the level of participation in social organisations. Furthermore, social isolation is one of the measures defining the social network of an individual. Many investigators have found social isolation alone to be a risk factor for ill health (Singer, 2018). Holt-Lunstad *et al*. (2015) found a 29% increased risk of mortality related to social isolation over time. Social isolation is the result of a decrease in social network size with a reduced number of social contacts. It can be either active, i.e. withdrawal from one's network, or passive, where an individual's social network moves or dies which is more often the case in older adults.

Seeman and Berkman (1988) provided a measure of social network and social support in their study. Social network structure was measured by a) size: totalling the number of social ties with children, other relatives and friends, b) number of relatives living nearby (same state), number of monthly direct face-to-face contacts and yearly indirect nonvisual contacts with network members, and c) number of long-distance ties (out of state). Specific ties (children, close relatives, close friends, spouse, confidante) were examined for the number of monthly face-to-face contacts. For social support availability two questions were asked, one for instrumental support- *"When you need some extra help, can you count on anyone to help with daily tasks like grocery shopping, house cleaning, cooking, telephoning, give you a ride?"* and two for emotional support- *"Can you count on anyone to provide you with emotional support?"*. For social support adequacy another two questions were asked, one for instrumental support- "*Could you have used more help with (daily tasks/emotional support) than you received?"* and another for emotional support- *"Could you have used more emotional support?"* For both items on adequacy, response options ranged from 'a lot' to 'none', in terms of whether they received sufficient support.

Glass *et al*. (1999) measured social networks through a series of questions that were designed to assess the important characteristics of networks (e.g. size, proximity, frequency of visual and non-visual contacts, and reciprocity) across multiple roles (children, other relatives, friends, confidant). Each question was asked separately for each role category.

Bassuk *et al*. (1999) developed the social disengagement index that measures social networks and social activities. They examined six indicators of social engagement: presence of a spouse, monthly visual contact with at least three relatives (children and other relatives) or close friends, yearly nonvisual contact (telephone calls or letters) with at least 10 relatives (children and other relatives) or close friends, frequent attendance (at least once per month) at religious services, membership in other groups, and regular participation in recreational social activities. The coding for this measurement is discussed in the methods chapter (chapter 6) in relation to this study's social network and social activity measures.

Berkman *et al*. (2000) used social network structure and social network function or characteristic to assess the social network of an individual. These structural components are measured in terms of range or size (number of network members), density (extent to which members are connected to each other), boundedness (degree of these connections such as kin, neighbourhood, or work), homogeneity (extent of similarities in network members). The functional components are frequency of contact (face-to-face, phone, mail), multiplexity (number of types of contacts), and reciprocity (extent to which these transactions are reciprocated).

Stephens *et al*. (2011) assessed the social network type by using the practitioner assessment of network type instrument (PANT) by Wenger & Tucker, (2002) as cited by Stephens *et al*. (2011). Responses to eight items regarding distance living from relatives, frequency of face-to-face contact with family and neighbourhood friends, and involvement in community groups, provide presence or absence scores on levels of the five different network types: family dependent, locally integrated, local self-contained, wider community focused, and private.

Escobar-Bravo *et al*. (2012) included both social network and social participation measures to assess network roles. The structural aspects of social relations were measured through the social network diversity and participation. A Social Network Index (SNI) was created that provided information about links at home, with children and grandchildren, with brothers and friends, intimacy, networking, social activities, and dynamism. The social network characteristics (number, proximity, frequency of contacts) were measured separately for each of the links. The sum score for the links provided a global indicator of network diversity, which was presence and strength of contacts in different types of links.

In summary, social network measures have developed, and become more complex and refined, rather than basic details on the number of social ties. The social network measures provided by Glass *et al.* (1997), Bassuk *et al.* (1999) and Berkman *et al.* (2000) have a lot of similarities in terms of classifying and defining social networks. The current study has generated its social network measures based on their work for use in the analysis.

2.4.3 Health benefits of social networks

The literature to date demonstrates a large amount of evidence showing the health benefits of social networks. Social networks and social support in particular have been found to exert significant effects on the health and general functioning of older persons (Berkman *et al.*, 2000, Unger *et al.*, 1999), quality of life, and depression (Jakobsson *et al.*, 2003; Roberson and Litchenburg, 2003). Studies have also revealed relationships between increased social integration/social support and better physical and mental health (Seeman *et al.*, 2001). Conversely, poor social connections, fewer social activities, and social disengagement in people above the age of 65 have been shown to predict a greater risk of cognitive decline over four years of ageing (Zunzunegui *et al.*, 2004). People with more social ties have lower risk of mortality (Seeman *et al.*, 2001). In another study, Stephens *et al.* (2011) conclude that both emotional and instrumental social support outside of the family, and a sense of social engagement, contribute towards better mental and physical health.

Social integration and support both lead to better mental and physical health outcomes (Berkman, 1995, Seeman, 1996). However, to maintain physical health, independence and a good quality of life, the major determining factor in older age is cognitive function (Seeman *et al.,* 2001). However, with advancing age the cognitive ability of an individual declines. Nevertheless, considerable differences exist between the rates and timings of these cognitive changes in older adults (Schaie, 1990 and Willis, 1991). Owing to a rise in the growth of the older adult population, it is important to understand the explanations behind these individual differences.

There have been good reasons to hypothesise that a social environment has an impact on the cognitive functioning patterns of an individual (Seeman *et al*., 2001). Social integration and its positive influence through protective effects of network size have also been hypothesised as affecting cognitive function (Basuk *et al*., 1999). Seeman *et al*. (2001) found that individuals reporting greater social engagement with others (a higher number of social contacts) exhibit slower declines in cognitive functions over time. Furthermore, they demonstrated that frequency of socially supportive interactions had the most impact on cognitive ageing. Both studies (Bassuk *et al.,* 1999 and Seeman *et al*., 2001) examined structural as well as qualitative aspects of an older adult's social network in relation to cognitive ageing and revealed a protective role of social networks on cognitive functions of an older adult.

Social relationships play a fundamental role in individuals' lives and health, and have previously been associated with physical and psychological wellbeing. Social isolation has been particularly prevalent with increasing age, with up to 50% of older people at risk of being isolated socially (Singer, 2018). A longitudinal Hertfordshire cohort study (Bevilacqua *et al*. 2021) found social isolation over a period of six years was associated with a higher odds of having depressive symptoms and poor physical capabilities in community dwelling adults. A prospective study over a period of four years by Kawachi *et al*. (1996) revealed that socially isolated men had a 90% increased risk of cardiovascular deaths, and more than double the odds of deaths from suicide or an accident. There have been many studies linking social isolation to poor health and these studies have assumed that health status contributes to one's ability to be socially engaged (Singer, 2018).

Empirical research has demonstrated that older adults with wider social relationships have better survival chances and therefore live longer (Glass *et al.,* 1999), and have better health and autonomy (Seeman, 2000). The frequency of contact with friends and strength of family networks has also shown protective effects against disability onset in older people (Mendes de Leon *et al*., 1999). Both the rapid growth of disability among older people (Escobar-Bravo *et al*., 2012) and the population growth of this age group has put an additional burden on health care professionals and researchers to identify the factors that influence the onset or progression of disability among older adults (Escobar-Bravo *et al*., 2012). Understanding this could help to reduce the long-term care and dependence situations in health care facilities and organisations.

The causes of disability are multifactorial, including physical, psychological and social factors (Link and Phelan, 1995; Dear et al., 1997). There is also evidence that the process of disability in the elderly can be accelerated because of biological and psychosocial changes associated with ageing (Link and Phelan, 1995; Regidor et al., 1997; Preston et al., 2005). The extent of social networks and the frequency of contact with friends, or the strength of the family network (Mendes de Leon *et al*., 1999; Mendes de Leon *et al.,* 2001; Avlund *et al*., 2004a; 2004b) have shown protective effects against the onset of disability, slowing its progression. Another study by Escobar-Bravo *et al.* (2012), on the protective effects of social networks on disability, found that the effect of different components of social networks is not homogeneous; it is more determined by social participation than by a social network structure. They defined disability as a difficulty in carrying out activities in any aspect of life, from hygiene to hobbies, from daily shopping to sleep, due to physical or health problems. In this study, a strong social network of friends and active participation in social activities seemed to protect the severely disabled; and the authors confirmed these results in a longitudinal retrospective analysis. Both social structure and social participation were significantly associated with basic disability (Escobar-Bravo *et al.*, 2012).

Throughout the literature, social networks and relationships have been demonstrated to have a protective relationship with health outcomes. There are a few significant explanations in support of this (Berkman *et al*., 2000; Uchino, 2006; Umberson *et al*., 2010; Umberson & Montez, 2010). These authors have argued that relationships have a moderating effect on adverse health outcomes by reducing stress and isolation and enhancing emotional support. In times of need, these relations also provide comfort. Relationships are also beneficial for behaviours such as keeping track of medical treatment, a healthy diet and exercise, and smoking cessation, through various cognitive mechanisms (see Shor & Roelfs, 2015, for further discussion). These relationships make instrumental assistance possible, which are crucial factors for maintaining health in older adults, as their mobility is compromised (Thoits, 2011 as cited by Shor and Roelfs, 2015).

All of these studies provide evidence for the protective role of social network measures, such as social relationships, support, engagements and interactions, and the detrimental effects of social isolation and disconnectedness on the functional and cognitive health outcomes and overall healthy ageing in older adults.

2.4.4 Loneliness and health in older adults

Social network measures, and in particular social isolation, expresses itself psychologically in an individual as a subjective measure, loneliness; that is dissatisfaction in the quality or quantity of their social contacts. Therefore, it encompasses the difference between the relationships an individual has and the relationships they would like to have (Smith *et al*., 2018; Bevilacqua *et al*., 2021). Significant negative health outcomes are associated with loneliness. These include an increased risk of cardiovascular disease, infectious diseases, cognitive decline and all-cause mortality (Smith *et al*., 2019). Loneliness, which is in particular prevalent in older ages, impairs quality of life by affecting both physical and mental health. It is evidenced in the literature that approximately 50% of older people were at the risk of social isolation and roughly a third of older adults experience some degree of loneliness (Grenade and Boldy, 2008; Landeiro *et al*., 2017; Bevilacqua *et al*., 2021). Loneliness is different from social isolation, and is a subjective measure; a negative assessment of the discrepancy between an individual's desired and actual quantity and quality of social relationships (Smith *et al*., 2019).

Although there is evidence that loneliness and social networks both have a detrimental effect on health (Golden *et al*., 2009), it is indicated that the relationship between the subjective perception of loneliness and health is different from the relationship between each component of the social network (such as network size, relationships, activity, engagement) and health. The relationships between loneliness and health also vary among different populations (based on social, economic and political constructs), across different countries and across generations (Rico-Uribe *et al*., 2016). Studies have found that the subjective experience of loneliness is more harmful to health than objectively measured numbers of social contacts. Therefore, although measures such as social relationships, contacts, engagements or social isolation are direct objective measures that can used to assess social networks, the same measures cannot necessarily be used for loneliness (Cornwell & Waite, 2009).

There can be objectively measured dimensions of loneliness, with a person considered socially isolated if they live alone, have less than monthly contact with friends or family, and don't belong to a group (religious congregation, club, work or volunteer organisation, etc.). However, defining isolation purely in quantitative terms may not always be valid. Research tells us that the quality of our social interactions, more than the number of our relationships, determines loneliness. Social isolation or disconnectedness is assumed to be a less stressful state and less detrimental to health when compared to loneliness or perceived isolation (one can be lonely even without isolation i.e., perceived isolation). However, research has not always supported this assumption (Cornwell & Waite, 2009). For instance, in a study where social isolation, with or without loneliness, was shown to have a large effect on mortality risk through smoking, obesity, sedentary lifestyle and high blood pressure (Cappuccio *et al*., 2010), it was also evidenced that even without loneliness, social disconnectedness could be detrimental to health status.

Being socially isolated for an older adult comes either as a choice or more often is imposed by the death of loved ones, the moving away of family and friends, impaired mobility, and other situations leading to depleted social networks. Studies have suggested that loneliness is a common problem among older adults similar to chronic pain. Loneliness and pain are positively associated. For example, people who felt socially disconnected were able to tolerate less physical pain than those who felt more socially connected, suggesting that feeling unconnected to those around you may increase pain sensitivity (Oishi *et al*., 2012). Although it is claimed that underlying factors for both physical and social pain have common brain mechanisms, the temporal relationship between loneliness and pain is still uncertain (Eisenberger, 2012). Eisenberger, an associate professor of social psychology at UCLA, in her experiment (online virtual game: cyberball catch with subjects) monitored the brain's reaction in brain scans of one player who was eventually excluded from game. Increased activity occurred in the subject's specific areas of the brain (dorsal anterior cingulate cortex and the anterior insula), the same two areas that also spring into action in response to physical pain. This showed that social isolation doesn't just feel like but it actually does hurt on a neurological level (Eisenberger *et al*., 2003).

Pain may limit activity and social engagement thereby contributing to loneliness, whereas the stress of loneliness may exacerbate pain (Loefler and Steptoe, 2021).

Furthermore, loneliness also contributes to an increased risk of physical and cognitive functional decline, mental ill health Hawkley *et al*., 2003), and cardiovascular disease (Chobanian et al., 2003). Lonelier people are more depressed than people who feel more socially connected (Jaremka *et al*., 2012), have more sleep problems (Irwin, 2002) and engage in less physical activities (Hawkley *et al*., 2009; Kurina *et al*., 2011). This creates complimentary pathways linking loneliness and poor health. Both sleep disturbances and physical inactivity in lonely individuals place them at higher risk for pain, depression, and fatigue leading to poor overall health (Berlin *et al*., 2006; McNeely *et al*., 2006; Cappuccio *et al*., 2010; Palesh *et al*., 2010; Landmark *et al*., 2011).

Loneliness is not just a subjective assessment of social networks and social interactions of the older adult population, but it is much more complex, sophisticated and distinct from the social network measures discussed above. The mechanism that underlies loneliness to influence health outcomes in older adults differs from the other social network measures. The scope for the current study focuses on the role of social networks and engagements on chronic pain in community dwelling older adults. This study aims to analyse data from the MBS on measures of social networks and chronic pain. Additionally, the MBS does not include measures of loneliness for its study population. Given the secondary data analysis nature of the thesis, it was not possible to include any measure of loneliness, and therefore loneliness is not included as a variable of interest for this study. Furthermore, for the same reason it is not justified to include it as a keyword search term for the review of the literature.

2.5 Conclusions

Pain is a significant problem among the older population, as both its prevalence and risk factors increase with age. This chapter has extracted evidence from the literature supporting the argument that pain has detrimental effects both economically and on health outcomes. Owing to the growth in the older adult population in the last few decades, it poses a considerable financial burden on society and health care resources. Chronic pain consequences affect the physical and mental well-being of older adults, thus compromising health related quality of life. Therefore, public health attention and intervention is needed.

Many studies in this review concluded that pain prevalence among the older adult population is high, greater in females than males, with site-specific (mostly lower limb) pain increasing with age among older adults. More importantly, pain that interferes with daily activities of everyday life increases incrementally; this could be because lower limbs are associated with movement and mobility. The lowered health status related to pain among older people was also considerably high. Therefore, this makes both activity limitation and participation restriction highly associated with pain, in older people; pointing towards social isolation and a lowered social activity.

Prevalence of pain demonstrated by the studies reviewed was mostly self-reported, which could potentially lead to an under estimation of the actual prevalence rates due to cognitive impairment hampering the reporting and assessment of pain. Questions relating to pain prevalence have mainly focussed on more recent pain episodes, to minimise the potential effects of declining cognitive functions. Comprehensive pain measures are seen as more beneficial for assessing chronic pain and its overall experience, and the current study has information on pain outcomes evaluated through comprehensive self-report measures (BPI scales), which is advantageous because it explores pain in more detail and provides knowledge about the various domains of pain such as severity and interference with daily activities.

Pain prevalence appears to be increasing in older adults over the last two decades. However, owing to methodological issues and different populations and measures used across these studies, prevalence rates should be treated cautiously, as other potential explanations are possible, such as better awareness and reporting of pain among older adults. In order to accurately determine whether there is a change in pain prevalence over the years, longitudinal study designs need to be employed to measure and estimate pain in the same sample population across time. This can also help evaluate temporal effects of pain in relation to other health outcomes. The current research study employs a dataset of a prospective longitudinal design, with measures of pain outcome at baseline and 18-month follow-up, which allows any change in pain prevalence rate for this sample to be observed. It will also help evaluate temporal relationship between social network status at baseline, and pain outcomes at baseline and 18-month follow-up.

It is clear that chronic pain is associated with unhealthy ageing or other health problems such as depression, mobility difficulty, social vulnerability and a lower health related quality of life. Studies also show that lower education and lower income are related to chronic pain. Risk factors such as socio-economic status, financial strain and education are all embedded in the social construct of an older adult. Many studies on pain risk factors revealed that social support, participation and social contacts were important indicators for pain outcomes in the older adult population. All this provides a justification to explore the role of social networks predicting pain outcomes in this population. The current study dataset has information on socio-demographic and health variables of its participants, which can be used to identify potential risk factors for pain in this sample population and compare it with data in the literature.

Management of pain is complex, with its prevalence and risk factors increasing in older people which is also due to various other health problems involved such as functional dependence, isolation and lower-self rated health, comorbidity and cognitive impairment. Therefore, it is important to understand the protective role of individual factors on chronic health outcomes, and pain outcomes in particular in order to better inform public health interventions designed to treat pain and its consequences.

The literature has provided supporting evidence for social networks, social participation, activities, and social interactions positively influencing the health outcomes in older adults. Furthermore, there is evidence that loneliness, a more subjective measure of social network, also influences chronic pain in older adults. However, it would not be possible to measure or evaluate associations of the qualitative measure of social network with pain outcomes for the scope of this study; but nevertheless, this study would be exploring the quantitative and structural measures of social networks and psychological pathways these networks utilise to influence pain outcomes. Hence, to manage pain it is important to involve a multidimensional model that takes into account all the factors embedded in the larger social construct, psychological and biomedical construct that influences the percept of pain.

Throughout history, various pain models have evolved to understand and explain pain as a phenomenon; more recently, chronic pain in advancing age is the dominant topic. Breakthroughs were made in the field of pain medicine through theories such as the Gate-Control model and the Neuromatrix model. More recently, the Biopsychosocial Pain model considered pain as a multidimensional concept, which aligns well with the conceptualisation of chronic pain. Effective strategies for coping with persistent, recurrent, or chronic pain are very different from those for managing acute pain. Psychological theories of pain focus on the need for a patient-centered approach to clinical care that takes into account individual differences in lifestyle, occupational demands, social support, health habits, personal coping skills, and other contextual factors when treating pain and related disabilities (Linton and Shaw, 2011).

There is also evidence that traditional biomedical approaches to treating pain can be enhanced if applied in conjunction with psychosocial (social, emotional, behavioural) approaches to treating pain and other outcomes such as the physical disability related to it. Recognising that an individual in pain is frustrated or beginning to severely limit activity might give reasons to adopt a more psychological or multidisciplinary approach that might offset some of the negative functional and social consequences of a developing chronic pain problem (Linton and Shaw, 2011).

There are, however, theoretical models to support the protective role of social networks and social activities on various health outcomes, some of which were briefly discussed earlier in this chapter under the history and health benefits of social networks. This study specifically will explore the protective role of social networks on pain outcomes, with the hypothesis that better social networks are associated with better pain outcomes. The following chapter (chapter 3) will introduce the earliest concepts and more current frameworks that link social networks to health. Furthermore, it will rationalise applying a chosen network model in particular to pain outcome for this study.

3. CONCEPTUAL FRAMEWORK, AIMS & OBJECTIVES

3.1 Introduction

Numerous studies have focused on the role of social networks in health and health changes. They have shown that social networks protect against a range of negative health outcomes both physical and mental (Glass *et al*., 1997; Berkman *et al*., 2000; Seeman *et al*., 2001; Zunzunegui *et al*., 2004). There are many theories in the literature that have formed the building blocks of empirical research of social relationships and its role on health outcomes. The earliest concepts emerged from sociologists, and later on from anthropologists and epidemiologists. More recent and advanced concepts have been developed by Glass *et al*. (1997) and Berkman *et al*. (2000), which in turn has generated new hypotheses related to the subject (e.g., Zunzunegui *et al*., 2004). These concepts were presented in the previous chapter. This study's hypotheses have been formulated based on the conceptual frameworks documented in the literature that demonstrate a positive relationship between social networks and health outcomes.

This chapter begins by describing the earliest theoretical orientations conceptualising and linking social structure, integration and attachment to health. It critiques the different theories and discusses the more evolved concepts underlying the relationship between social networks and health. It then goes on to outline this study's conceptual model, and the rational behind choosing the model, explaining its network consisting of macro, mezzo and micro factors that follow a social network pathway to predict health outcomes. Towards the end of this chapter, an explanation on how the chosen network theory fits the current model of pain will be presented.

3.2 Earliest theoretical orientations & the current study framework

The study of social networks was initially borrowed from the field of anthropology where social relationships were explored to study trading patterns, mate selection, and local politics (Tsai and Papachristos, 2015). Emile Durkheim made the most innumerable and earliest contributions to the field in the late 1800s, identifying that social relationships played a role in physical and mental health (Berkman *et al*., 2000; Tsai and Papachristos, 2015). Durkheim's key finding was on how the individual pathology was a function of social dynamics, in other words, how social integration had a role in mortality. His theories were mostly related to the patterning of suicides, but were easily extended to violence, homicides and even cardiovascular diseases. Durkheim illustrated in *Suicide* that the depletion of the societal ability to integrate triggers suicide (Berkman *et al.,* 2000). This theory conceptualised how the patterning of any psychological and intimate (on the surface) act was laid down not just on psychological foundations but upon the patterns of social facts.

One of the most important scientists of the twentieth century was John Bowlby (Storr, 1991), who proposed through his work on *Attachment* that there is a universal human need to form close affectionate bonds (Fonagy, 1996). Attachment theory by John Bowlby proposed that environment, especially in early childhood, had a crucial role in the origin of neurosis, however this theory also relates to adult development. In adulthood, Bowlby saw marriage as the adult equivalent of attachment between infant and mother (Berkman *et al*., 2000). According to Bowlby, the separation of infants from their mothers was unhealthy; he believed that loss and separation were key issues for psychotherapy (Cassidy *et al*., 2013). This theory, however, was established in response to tackling the caregiving experiences of parents with their infants, and to improve the process of child development for mental and overall health. It focused on the problems of the parent-child relationship and how that influenced the future health and development of an infant into childhood and adolescent (Cassidy *et al*., 2013). The strength of Bowlby's theory lies in an individual’s expression of need for security and support such as through a healthy marriage, if secured it can form a protective shell for times of need (Holmes, 1993). In addition, it was theorised that early childhood bonds form a solid attachment in adulthood and promote social relations in larger systems of society (Fonagy, 1996). Early childhood emotional development has been recognised widely as an important and critical development phase of an individual, not only for cognitive or emotional development but also for overall health (Berkman *et al*., 2000; Cassidy *et al*., 2013).

During the 1950s, Barnes and Bott were the first to come up with the concept of social networks, i.e. structural arrangements and social institutions (Berkman *et al*., 2000). Their social network theory focused on the characteristic patterns of ties between individuals in a social system rather than just on characteristics of the individual themselves (egocentric network); and further on the uses of these descriptions to study how social structures constrained network member's behaviour

(Hall and Wellman, 1985). This is similar to the Durkheim view where the social institutions and its resources played a role in individual's behavioural and emotional responses (in triggering suicide), for instance in situations where economic and political crises lead to weakened social control regulating integration (Turner and Noh, 1983). Even though in essence this work was positioned on similar foundations of that of Durkheim (a focus on suicide as an outcome), social network theory explicitly placed an individual as connected at all levels (individual, community, organisational) and hence recognised the role of a whole (socio-centric) network on individual behaviour. It focused on the more distal (to an individual) factors that plays a role on an individual's outcomes/behaviour in a society.

In contrast, the social scientists in health psychology have typically focused on the qualitative aspects of social relations (in the form of support) and not just elaborate structural (such as size, density, frequency of visits) aspects of social networks. One of the most important contributions to social network research by Lin and colleagues was the social resource theory (Lin *et al*., 1986). This helped understand the ways by which support (a more qualitative aspect of social network rather than quantitative aspect) was linked to mental health. However, the investigators followed the assumption that the most significant factor influencing health in an individual's network was the support it provided. It therefore only focused on the proximal pathway between social relationship and health outcome, ignoring the social context and structural underpinnings that define the extent of social support (Berkman *et al*., 2000). Even though this resource theory was able to shed light on the nature of support and the quality of networks, it ignored the more distal factors that shape and regulate the social relationships of an individual.

A much more comprehensive framework which focused on the distal factors to health such as social context and structure (Durkheimian orientation) along with the more proximal factors related to health such as social support (emotional and instrumental such as the resource theory approach), and including social engagement and activities was conceptualised by Berkman *et al*. (2000). According to Berkman *et al*. (2000) social networks profoundly influenced health outcomes. Their model follows a systematic empirical approach to explore the role of social networks and health by capturing the earliest concepts laid down by Durkheim along with the rapidly developing methodological advancements by health care organisations, health professionals, clinicians, and researchers in health (Tsai and Papachristos, 2015). This conceptual framework firstly helps to understand the determinants that form social networks and secondly it interprets the mechanisms through which social networks affect health. This framework is described in detail in the following sections including its strengths and limitations.

Two decades have passed since the authors conceptualised this framework, and even though the essence of the model among various researchers is indisputable and provides opportunities for a myriad of variables to be considered, very few studies (Zunzunegui *et al*., 2004; Frazer and Rodgers, 2009; Stephens *et al*., 2011) have employed this framework. To date, this framework is the most recent and developed model available, providing a structure of causal effects and clear conceptual categories for the different levels of social influence on health.

3.3 Conceptual model linking social networks to health: an overview

There were many studies throughout the 1970s and 1980s, which demonstrated that a paucity of social ties and networks predict greater mortality from almost every cause of death (Kaplan *et al*., 1988; House *et al.* 1988; Berkman, 1995). The network measures were conceptualised in many ways, such as assessments of social ties, social connectedness, integration, social networks, and social engagements or activity (Berkman *et al*., 2000; Stephens *et al*., 2011). The interpretation of these measures, and what they actually measure, has been debated (Berkman *et al.* 2000), but their potential role in predicting health outcomes has become much clearer with time owing to a number of studies showing a protective influence of social network, ties, support and the integration on health outcomes in older adults (e.g., Bassuk *et al.* 1999; Zunzunegui *et al.* 2004; Peat et *al*. 2004; Stephens *et al*., 2011). There is a general consensus that social networks provide a support function. Social support is among the primary pathways through which networks influence both physical and mental health. However, Berkman *et al.* (2000) argued that social support is not the only critical pathway, stating that focusing only on social support limits understanding in cases where large and complex networks with social support still indicate poorer health outcomes or less adaptive behaviour. Berkman *et al.* (2000) predicted a series of cascading causal processes from macro, mezzo and micro-social to psychobiological factors that link together in a dynamic fashion defining the routes by which social constructs and networks influences health. They proposed a comprehensive framework explaining the phenomena of social networks and its influence on health by including both proximal and distal factors through an upstream and downstream pathway (see Figure 3.1); where the terms proximal and distal refer to the closeness of social factors to the individual (Berkman *et al*. 2000). The upstream pathways form social networks are embedded in larger social and cultural contexts, and the downstream pathways help to further understand the influences of these networks on interpersonal behaviour and engagement in network activities at an individual level. Therefore, according to this model, the networks operate through two approaches, upstream and downstream. This model has been used in studies to investigate the relationships between social and psychological constructs of the model and health outcomes (Zunzunegui *et al*., 2004; Frazer and Rodgers, 2009; Stephens *et al*., 2011). More detail of what is considered in the upstream and downstream pathways are now considered.

3.3.1 Upstream pathways

Upstream pathways are a group of factors that involve macro-social and network elements. The macro-social element has social changes, political, cultural, and socio-economic conditions. These further shapes the nature of mezzo factors that have social network elements comprising of the structure and characteristic (function) of a network (Berkman *et al*., 2000).

Macro factors include social changes like urbanisation, and political factors include public policy or political culture. Culture factors include norms, values, and social cohesion, and socio-economic factors include inequality, discrimination, and poverty.

Mezzo factors are social network structures that include network size, density, boundedness and proximity with network ties (e.g., family, children and friends), and function that includes frequency of face-to-face or non-visual contact, duration, and reciprocity of contact amongst others.

3.3.2 Downstream pathways

Downstream pathways are the means by which social networks (from upstream pathways) influence health outcomes. The structure of network ties influence health by providing opportunities for basic types of support. These include a group of factors that involve psychosocial mechanisms operating in the following ways: (1) provision of social support; (2) social influence; (3) social engagement; (4) person-to-person contact and (5) access to resources and material goods.

Additionally, these elements influence the pathways of health outcomes through: (1) Behaviours: health-damaging behaviours such as tobacco consumption or high-risk sexual activity, health promoting behaviour such as appropriate health service utilisation, medical adherence, and exercise (2) Psychological pathways: states and traits including self-esteem, self-efficacy, depression (3) Physiological pathways: direct stress responses, immune system function (Berkman *et al.*, 2000).

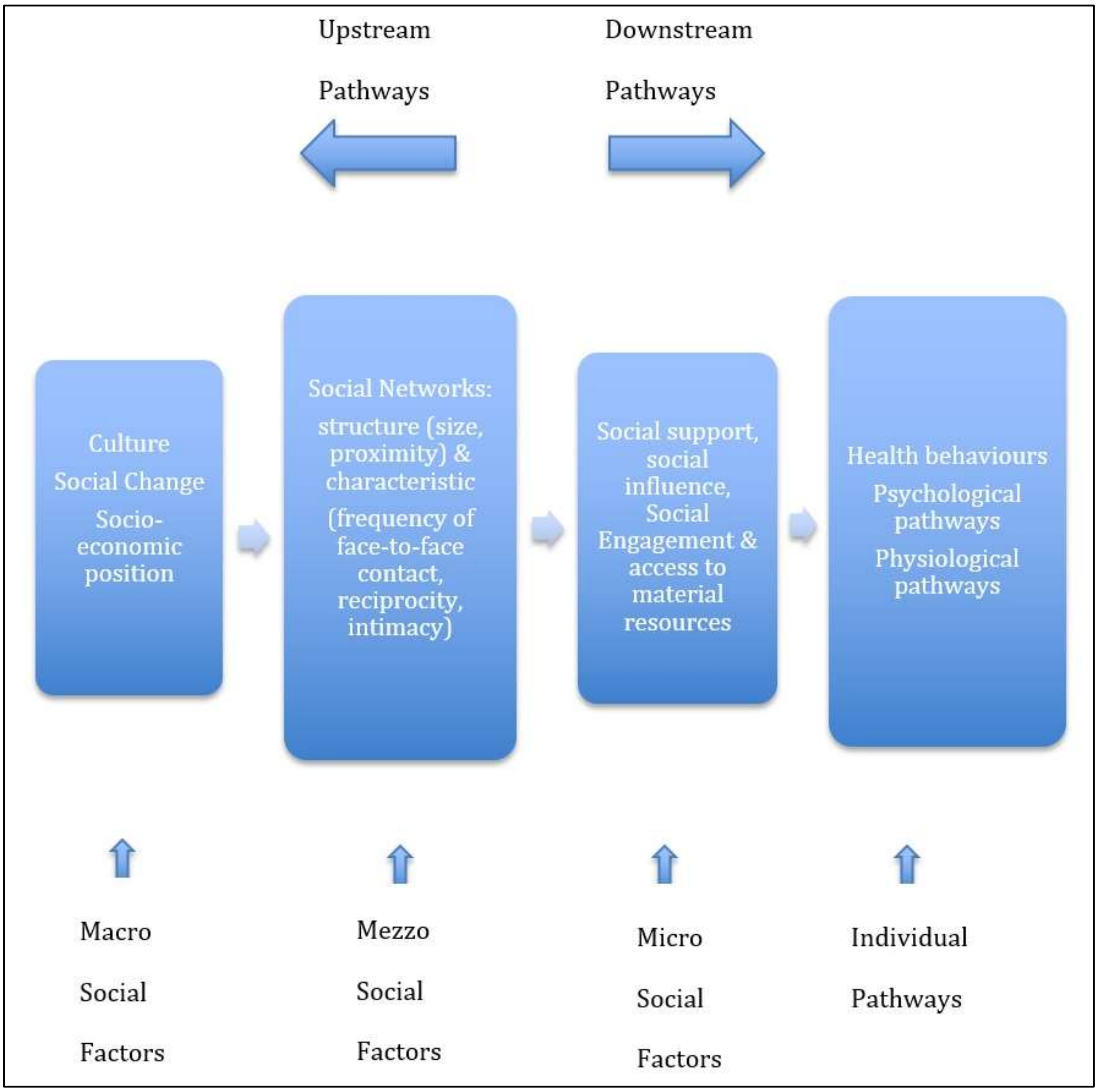

Figure 3. 1Social networks influencing health outcome (Berkman et al., 2000)-A comprehensive network showing the effects of social environment on health outcome of an individual. Macro social factors influence mezzo-factors (which are upstream i.e. factors further away from an individual), which impacts the micro social factors that in turn influence individual pathways (which are downstream i.e. factors closer to an individual) that potentially determine the health outcomes.

3.3.3 Current study framework, strengths and limitations

This study uses Berkman *et al.*'s (2000) framework to explore the influence of social network and social activity on chronic pain severity and interference in older adults. The research hypothesis predicts that the upstream macro factors of this model (socio-economic variables such as race, gender and years of education), mezzo factors of the model such as structural social network (number of social ties- non-visual social network) and functional social network (face-to-face contact with these ties- visual social network, proximity and intimacy- someone to depend upon), and downstream micro factors of this model (variables such as social activity score) will have an association with health outcomes, specifically pain outcomes of severity and interference with daily activity. These factors (upstream and downstream) align very closely with the variables of the MBS dataset that this study will analyse. The model will be used to explore associations between macro, mezzo, micro social network factors and pain outcomes through the secondary data analyses of the MBS dataset, and demonstrate whether the model can be extended to the prediction of pain outcomes in older adults. Based on the model's framework, there is a relationship predicted between the macro social factors of this model, as measured by socio-economic factors such as race, gender, education variables in current dataset), mezzo social factors (non-visual, visual social network, someone to depend upon) and micro (social activity) factors. Figure 3.2 below is an adapted version of the social network framework by Berkman *et al*. (2000) and depicts the upstream and downstream factors that are predicted to influence pain outcomes in the older adult population of the MBS.

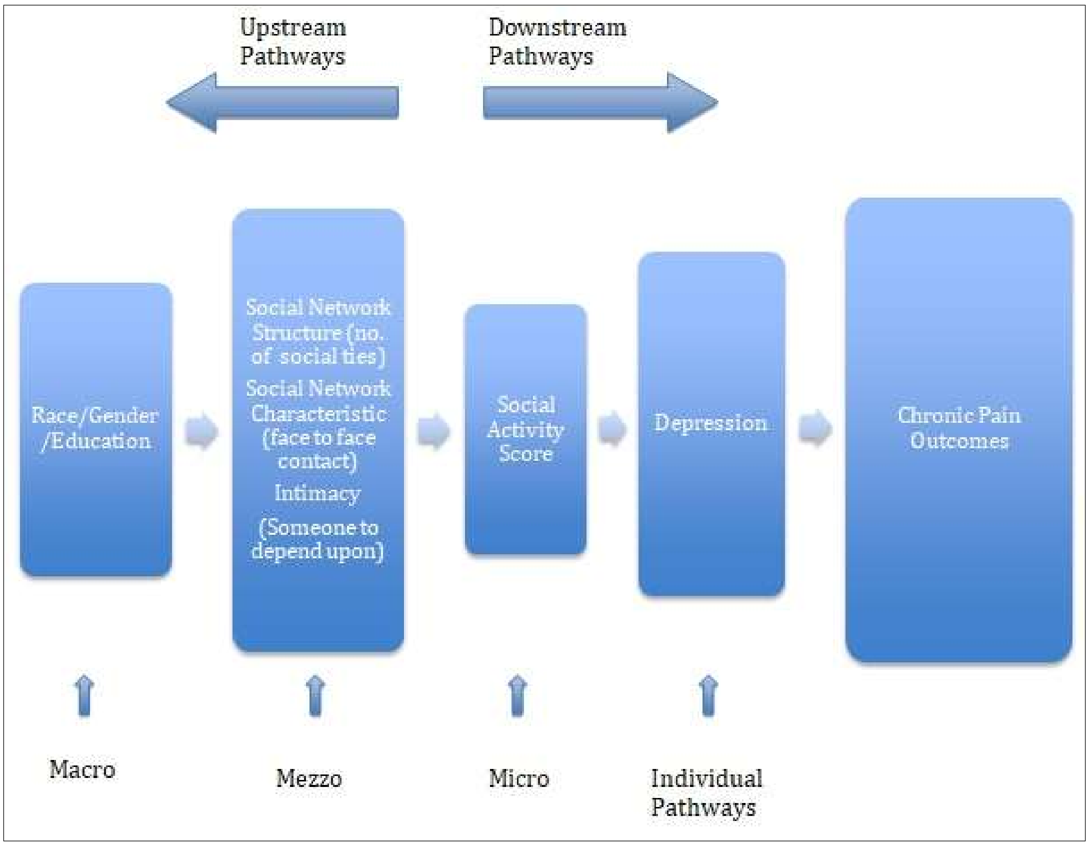

Figure 3. 2 Social networks influencing pain (adapted from Berkman et al., 2000)- An adaptation of the comprehensive social network theory by Berkman et al. that explains how social environment of an individual potentially can affect the chronic pain outcome. Upstream pathways (macro and mezzo factors) may influence downstream pathways (micro and individual factors) to potentially impact chronic pain outcomes. Macro social factors consist of race, gender, and education; mezzo social factors consist of social network structure, social network characteristics and intimacy; micro social factors consist of social activity; and individual factors such as depression.

This study's framework is enhanced through the use of the Berkman *et al*. (2000) model due to the clarity it provides between a confusing array of constructs in the social relationships and health area. Along with providing a structured basis in accounting for relationships, it includes the wider social context. It is not just evolved, progressive and comprehensive, as well as having been cited more than 1500 times (Tsai and Papachristos, 2015), but has also been the theoretical framework for cohort studies such as Zunzunegui *et al*. (2004) and Stephens *et al*. (2011) hypothesising the protective role of social networks on health. It has also proven to be valid for the older adult population. Fraser and Rodgers (2009) have used the model to test the higher-level social factors of social status, income, and marriage with social networks and social support among heart patients. They found that higher social status and income were related to larger, more diverse networks and more social support. The current study, for the reasons mentioned above orients its hypothesis around this framework.

However, it is important to acknowledge that even though there is a strong rationale for the use of the Berkman *et al.* (2000) framework owing to its various strengths, it has its limitations too. Although many of the current MBS dataset's variables of interest align with the measures included in the framework, there are still important measures missing or a lack of depth on information on those measures. In addition, to test the framework, measures were validated for the variable under investigation at the time, which could be an issue. The current study is a secondary data analysis, which makes it impossible to test all the required measures in the framework to find associations between macro, mezzo, micro social network factors and pain. Therefore, the comprehensiveness and robustness of the framework may act as a limitation when tested to find associations and causality. More importantly, testing the model requires time, expense, resources and a prospective cohort design to find a casual connection between social networks and the health outcome under investigation, another challenge for a secondary data analysis. With the current dataset (secondary data), an observed statistical association between exposure and disease outcome does not necessarily lead us to infer a causal relationship. In such cases to conclude a cause-effect relationship between exposure and disease requires inferences far beyond the data from a single study (Barratt and Kirwan, 2009; Shantikumar, 2018).

3.4 Theoretical framework & its fit into the current pain model

The theoretical framework by Berkman *et al*. (2000) encompasses the Durkheimian view of distal social construct along with the more proximal social factors influencing health. This fits within the biopsychosocial model (discussed in the previous chapter), which hypothesises that pain is the result of complex interactions between biological, psychological and sociological factors (Lopez-Martinez *et al*., 2008). In the late 1970s, the biopsychosocial model was scientifically robust as an explanation for the etiology of some medical conditions. It was claimed that to treat a disease adequately, one must consider multidimensional concepts. This methodology took into account the fact that illness and disease were the results of complex interactions between biological, psychological, and sociological factors, and in combination they affect the physical and mental well being of an individual, and in the present context chronic pain. Furthermore, failing to consider any one of these elements when determining the cause of pain will contribute to an incomplete assessment and management. Therefore, since the theoretical framework by Berkman *et al*. (2000) takes into consideration factors related to the environmental (social, political, cultural, economic) conditions in which the individual is embedded and the closest factors related to individual (for instance health promoting behaviour like exercise, medical adherence, psychological responses like stress, depression and physiological responses such as immune regulation), it proves a worthy fit with the biopsychosocial model of pain. Based on the bio-psychosocial pain model, several psychological factors play an important role in the genesis, exacerbation, and maintenance of recurrent pain conditions, which are cognitions, coping responses and social environment variables (Andrasik *et al*., 2005; Jensen *et al*., 2002 cited in Lopez-Martinez *et al*., 2008), all of which are directly or indirectly measures of the comprehensive social network framework in the current study.

3.5 Overarching aim of the study

The overarching aim of this study is to explore if there is a relationship between the quality and quantity of social networks and engagement in social activities with outcomes of chronic pain in the older adult population.

3.5.1 Study objectives

The first objective is to conduct a literature review identifying studies that have explored the association between social networks/activity and pain outcomes in community dwelling older adults. The rationale for this approach is not to synthesise study outcomes for a definitive answer but more to systematically identify (so as not to miss anything) all the studies generated in this area and to extract information useful to this study.

Drawing on the results of the systematic literature review, the second objective will be to perform a secondary data analysis of the MOBILIZE Boston Study dataset and conduct regression analyses exploring associations between social network/activity and pain outcomes in older adults.

In order to conduct a secondary data analysis of the MBS dataset, social network variables will be created using the information provided on social ties (number of children, relatives, friends and frequency of visits from children, relatives and friends, and the presence of a confidante). A six item BPI pain interference variable will be calculated from the original seven item measures, to avoid correlation between a single item on the BPI that measures relationships with people and the independent variables of social network and activity which could artificially inflate the association between pain and social networks. After establishing the independent and dependent variables, the cohort characteristics of the MBS at baseline will be explored using descriptive and summary statistics. This will be followed by a regression analysis of the relationship between social networks/social activity and chronic pain outcomes in older adults, and the independent contribution of social networks/social activity to the prediction of variance in chronic pain outcomes in older adults after controlling for potentially confounding variables. Finally, regression analysis of baseline social networks/social activity measures on chronic pain outcomes at 18-month follow-up will also be conducted to explore longer-term effects of social network/activity variables on pain outcomes in older adults.

The various testable hypotheses that are generated to address the above-mentioned objectives in order to achieve the overarching aim will be discussed in detail in the methods chapter (chapter six).

4. LITERATURE REVIEW

4.1 Chapter overview

The first aim of this study is to identify any research that has explored the role of social networks/activity on chronic pain outcomes in community dwelling older adult populations. To achieve this, this chapter presents a review of the literature on social networks and pain outcomes in community dwelling older adults. The main purpose of the review is to identify what is already known about the association between social networks and pain outcomes in this population. Conducting an initial systematised review of the literature before going on to conduct secondary data analysis (of the MBS dataset) will guide the understanding of the measures used to define both predictor variables and outcome variables used in the analyses. This review will also provide an up-to-date and in-depth overview of social networks and pain outcomes that can inform public health policy and practice and help scope the viability of future research on social networks and chronic pain outcomes in older people.

4.2 Introduction

A review of the literature is an essential component of academic research since it leads to knowledge advancement based on existing work in particular subject areas and identifies gaps within the area of interest (Xiao and Watson, 2019). According to Templier and Pare (2015), literature reviews can be broadly divided into two types (1) a general literature review to serve as a background for empirical research (2) a stand-alone literature review to describe, test, extend and critique the evidence. The current review of the literature was conducted with the defined purpose of scoping and identifying gaps in the research on social networks/activities and pain outcomes in older people.

The background chapter depicted chronic pain as a major public health issue affecting substantial numbers of older adults in the general population. Additionally, studies conducted by Zunzunegui *et al*. (2004), Stephens *et al*. (2011), Cacioppo and Cacioppo (2014), Lee *et al*. (2015) and Shvedko *et al*. (2018) all provided supportive evidence of social networks, support and connectedness throughout the lifespan being an important aspect of physical and mental health as well as successful ageing. Based on this evidence, a more focused review of the literature was conducted proposing that social networks/activities have a beneficial effect on chronic pain in older people.

4.3 Methodology

This section describes in detail the search strategy carried out to collect all relevant literature pertaining to the present research question, which intends to explore the influence of social networks/activities on chronic pain outcomes in community dwelling older adults. It provides the search terms and keywords that will be used to identify all significant research papers. It also explains the selection criteria required for the included studies and describes the steps that were taken to conduct the review starting from the selection criteria, systematic search, screening of the search results to shortlisting included studies (PRISMA flow diagram), quality and eligibility assessment, data extraction, and lastly the result synthesis from the included studies.

However, before going on to conduct the search, it was important to formulate a specific research question and also establish and confirm that there wasn't any such reviews conducted already.

4.3.1 Research question

What is the role of social networks (family and friends), social activities and engagements on pain outcomes (severity and interference with daily activities) on older adults living in the community?

4.3.2 Identifying the need for the review

The first step was to identify if there was an existing or on-going literature review on the current research question (Denison *et al.*, 2013). This was done through searching the following databases: Evidence for Policy and Practice Information (EPPI) Centre and the DoPHER (Petticrew and Robberts, 2006). Another search for the current review question was conducted on the PROSPERO database that systematically records literature reviews on health, social care, and public health (Denison *et al.*, 2013). The COCHRANE database was also searched as it produces literature reviews on effectiveness of healthcare interventions.

In addition to the above, a search on Health Science Research database was conducted on the EBSCO-Host with the keywords in search along with the term literature review. Once confirmed that there were no previous completed or on-going literature reviews found on the above-mentioned databases that addressed the current research question, a literature review was conducted.

4.3.3 Systematic literature review

Systematic reviews are considered the gold standard in evidence-based decision-making when judging the effectiveness of a therapy or intervention. Systematic reviews, and in particular those that include meta-analyses, are placed at the top of the hierarchy of evidence (Marinho 2008). They aim to aggregate all information available to answer a specific research question, aiming to minimise bias by using clear systematic methods (Higgins 2011). The approach taken to conduct a systematic review is much like that of a scientific experiment, with high priority given to the transparency and reproducibility of the methods used and to handling all evidence in a consistent manner (Denison *et al.*, 2013). However, for this study, the literature review did not aim to provide evidence for any intervention, or solely collect, describe and extend the background literature on a specific research question; rather it was meant to identify gaps, define pathways for conceptual assumptions and generate support in favour or against the study hypotheses. For this reason, a general review was conducted on the current research question to corroborate background literature. Even though the reason behind conducting a review can differ depending upon the research question and experimental study at hand, they are still required to be valid, reliable and repeatable (Xiao and Watson, 2019).

Following confirmation that no literature review on the research question existed, this was to be the first of its kind and therefore it was envisioned to help a) provide comprehensive background evidence on the problem of pain and how the role of social networks affects pain outcomes in older adults, b) better understand what is already known about the complex nature of social networks in older people living in the community c) and what gaps remain that need to be bridged.

4.3.4 Selection criteria

According to the World Health Organisation (WHO), the chronological age for the determination of an older adult population is ≥65 years. Therefore, papers focused on this age range were selected. This was deemed suitable for this literature search because it ensured most of the working population was separated from the older adult population, and therefore the occurrence of pain or its risk factors could be identified for older adults without too many confounding effects of work related pain. However, it should be noted that even after the age of 65 years, people still work, and retirement does not necessarily mean that work related pain would not continue into later life. It was anticipated that chronic pain due to ageing would be identified through this literature search. Additionally, by not including any data on younger adults (<65 years), this study would make better inferences regarding the extent of the problem of pain in the older adult population and the potential supportive nature of social networks for this age group. Older adults are more likely to be affected by social isolation and are likely to be more in need of help and support from their social networks due to cognitive and physical decline. Therefore, for the purpose of this review, it was ensured that studies focussing on community dwelling older adults and their social networks were specified. This ensured that conclusions made from this review and in-turn this study were valid, and hence generalisable to older adults only.

A specific inclusion and exclusion criteria was employed. These specified the type of studies, type of participants, the type of exposures and the type of outcomes.

Inclusion Criteria

Type of studies: the study design was an important criterion to look for when shortlisting papers to be included in the current review. To find answers to an epidemiological research question, a well-defined source population is required. Study designs have various features that make them more or less suitable for investigating a particular exposure–outcome relationship (Checkoway *et al.,* 2007). For the current research question, large observational cohort studies with a prospective longitudinal design were shortlisted. This is because such studies follows a group of similar cohorts who differ with respect to certain factors (exposures under investigation) and determine how these factors affects their health outcome. This study design also entails a follow-up of the population over a period of time to determine the subsequent occurrence of a health outcome under different exposures. Therefore, the best design to explore and understand the current research question would be a longitudinal study. However, cross-sectional studies were also shortlisted if all other inclusion criteria were met.

Demographic characteristics of participants: the age of the participants was an important inclusion criterion as the current study only aims to explore the role of social networks on pain outcomes in older adults. The age group of ≥65 years was included in the current study analyses. Both male and female participations were eligible to ensure more generalisable results and conclusions, and lastly, residents of community dwelling populations were exclusively made a criterion for studies to be included. Nursing/care home populations were not included due to social network/activities likely to vary between residence types, with more institutional social interaction and formal social support in care homes due to nursing needs of residents. This decision was evidence based from background literature where formal social support and social interactions from nursing staff is provided for older adults with chronic conditions.

Type of Exposures: the below mentioned key words were considered for inclusion. These key words were decided based on the background literature on measures and definitions of social networks and various studies conducted in background to explore the social networks of older adults to see how it influences their other health outcomes. Many studies in the wider literature have focussed on a range of social support variables, however the current study mainly focussed on non-visual and visual social networks as per the structural and functional definitions of social network provided by Glass *et al.*, (1997), and social activities. However, while searching for literature on social networks, the term social support was also included because leaving out studies on aspects of support might exclude important research. It was important to capture studies that focussed on any aspect of an individual's network and its effect on pain outcomes, including social network (e.g., number of children, friends or relatives, social ties etc.); social support (e.g., someone to turn up to in crisis or someone to depend upon, a confidante or access to resources etc.); social relation (e.g., intimacy or frequency of face-to-face contact with children, friends, and relatives, etc.); social activity (e.g., group activities in a society, attending church activities, playing golf, member of an organisation); and, social engagement (e.g., connection with the community, feeling of self-worth and achievement through community engagements, etc.), social interaction (visiting family or relatives or friends, interaction through phone or messages) and social disconnectedness (disengagement from the community, not regular on attending community clubs, churches etc.).

Type of Outcomes: pain outcomes such as pain severity or intensity and pain interference with every day activity were included. Pain is a subjective and a complex measure especially in older people, as explained in the review of the wider literature in the earlier chapter (chapter two). Older people frequently suffered from severe or disabling pain (Docking *et al.,* 2011; Brown *et al.,* 2011); therefore studies with pain severity measures were included. Also, disabling pain could cause functional limitations in these older adults (e.g., Thomas *et al*., 2004; Fransen *et al*., 2014); therefore, studies measuring pain interference with daily living were included.

Chronic pain in older people was also characterised by specific physical location. Older adults often suffered from pain specifically in lower limbs (e.g., lower back, knee, hip) or weight bearing regions (Fransen *et al*., 2014). However, studies on any pain location were included for the purpose of inclusivity.

Pain outcomes included in the study were chronic and thus by definition needed to be present for more than three months. However, studies reporting pain in the last four weeks were also included because papers on chronic pain often restricted the reporting period to four weeks to buffer against any potential effects on memory from cognitive impairment, manifested in this age-group in the population. Table 4.1a lists the inclusion criteria for the current literature search.

Table 4.1 a Inclusion criteria for literature review.

Inclusion criteria	
1. Type of studies	Observational: longitudinal, prospective cohort design and cross-sectional study.
2. Demographic characteristics of participants	Age >65 years, male and females, community dwelling.
3. Type of exposures	Social network, support, relationships, activity, engagement, interaction, disconnectedness.
4. Type of outcomes	Pain (chronic, persistent, interference, severity)

Exclusion criteria

The following population-type, population-age and pain types have different aetiology or risk factors, and therefore, did not fit in the current study research question.

Type of population and type of exposure: Younger adult population or working population - pain in working population can be occupational-related, which was not within the scope of the current research and were excluded. Participant's specific to nursing homes or care homes - social networks in nursing/care homes are mostly considered formal social support that include activities by the nursing home carers and staff (Matos *et al*., 2016), which were different when compared to community dwelling participants, hence excluded. Social interactions and social network related to work and formally provided social support and interactions were outside the scope of the current research, hence excluded.

Type of outcome: Pain due to cancer and post-surgical pain or labour pain - pain in cancer patients could be due to medication, therapy and also due to other health problems of the critically ill; post-surgical pain was usually related to healing process pain, could also be acute in most cases; labour pain had a completely different aetiology and physiology therefore excluded. Table 4.1 b lists the exclusion criteria for the current literature search.

Table 4.1 b Exclusion criteria for literature review.

Exclusion criteria	
1. Type of studies	Conceptual paper, controlled trials (with support and interaction provided formally, pain tasks provided in controlled environment)
2. Type of population	Working adult population with participants under 60 years of age, participants residing in nursing and care homes
3. Type of exposure	Formal social support, institutional social interaction
4. Type of outcome	Pain due to cancer, post surgical pain, labour pain, pain due to medication and therapy in critically ill patients

4.3.5 Literature search

A comprehensive search was conducted to ensure an extensive coverage of the literature. MEDLINE is a preferred primary database for healthcare research (Denison *et al.*, 2013), and was therefore included along with other databases for health sciences research; Academic Search Premier, PsychInfo, CINAHL Plus, PsycArticles, Psychology and Behavioural Sciences Collection. These were considered the most relevant databases for the investigation of social networks and pain outcomes.

The search strategy covered a range of controlled vocabulary and free text terms, which were first combined using the "OR" Boolean operator. This produced a large number of articles and therefore distinguishing the use of "AND" "OR" Boolean operators helped shortlist articles focussing on the review question. The subject of social networks and its role on pain outcomes was explored. The background literature review from the previous chapter identified that social networks and its role on health outcomes in older people were still evolving, with very recent developments on the topic. Therefore, it was decided to have an open date range, in order to include all the research done on the current topic to date. Hence, there were no limiters applied such as any specific dates, to make sure most of the relevant literature could be captured for the review.

Search terms were decided after reading key papers on the subject area of social networks and social engagements in older people. Search 1 had all the possible key words that tried to capture both structural and functional aspects of social networks, social activities etc. Keywords such as social isolation, social disconnectedness and social interaction were also added in this search as they were deemed related to social networks of older people based on the papers presented in background literature. Search 2 comprised of different key words specifying older people; adult was excluded from the search term because the present review was exclusively meant for older people whereas the term adult would have included all adults and in turn would have included pain related to work, exercise, and injury as opposed to pain primarily related to ageing. Search 3 consisted of the keyword pain. There were however, other terms such as discomfort, distress, pang, ache, cramp that was thought to be synonyms for pain and hence added to search 3 as an initial trial search. This yielded a couple of thousand more studies when compared to the search with pain alone as keyword. Nonetheless after reading the titles and abstracts of around five to six hundred, it showed a trend of papers that focussed either on psychological stress or studies related to depression, health related quality of life etc. Papers that came up with search term ‘aches’ had the term pain in them as well. Also, the pain definition that this study focussed on was physical pain, bodily pain, chronic or persistent pain, or pain explained by different pain measurement scales. Terms such as distress and discomfort did not fit into this criteria and the pilot search illustrated that with the other terms in search 3, therefore the trend of papers that came up were not relevant to the study’s research question. Ultimately it was decided to keep pain alone as a keyword term in search 3 which yielded the required search results for the scope of this review.

After all the potential keywords were entered into the three searches, the “AND” Boolean operator was used to combine these three search terms. Truncation technique was used to search a portion of a word with an asterisk sign (*). This helped to locate key words spelt differently in a paper due to differences in the English language. See Table 4.2 for the key words used.

Table 4. 1 Search Terms for the review of the literature on social networks and pain outcomes

Search 1	Search 2	Search 3
Social Network* OR Social Support OR Social Relation* OR Social Activit* OR Social Engagement* OR Social Isolation OR Social Disconnectedness OR Social Interaction*	Old* OR Elder* OR Geriatri*	Pain

4.3.6 Data collection

The following section describes in detail about how the studies were identified for selection, checked for bias and quality of research in them; and how data were extracted and presented for further analysis.

4.3.6.1 Identification and selection of studies for inclusion

After running the search using the search terms mentioned earlier (refer to table 4.2), on the central databases described above (refer to subheading 4.3.5), the screening of studies for eligibility and selection was performed. This screening was done in the author's registered account for these databases based on key words, titles and abstracts. The record of those studies, which were not relevant for the current research question, were discarded. Identification was performed keeping in mind the inclusion and exclusion criteria and all identified studies were imported into Mendeley the reference manager (https://www.mendeley.com/reference-management/reference-manager).

A list of included and excluded studies were to be tabulated separately so that they could be presented in the results section with characteristics of individual studies (for the included studies) and the reasons for their exclusion (for the excluded studies).

4.3.6.2 Data extraction from included studies

After the selection criteria were applied and studies were included, the next step was to extract relevant data from the studies. This process of data extraction allows for locating relevant information in the included studies (Denison *et al*., 2013). Information on study design, characteristics and findings can be synthesised through this process, and using a standard data extraction form provides structure and consistency (CRD, 2009; Denison *et al*., 2013). Furthermore, this reduces bias and improves reliability and validity (Higgins, 2006). The form is usually required to be tailored to the specific review and what descriptive or analytical data needs to be presented in the review (Denison *et al*., 2013). A data extraction form was prepared based on the example information provided by the Centre for Reviews and Dissemination (CRD, 2009) guidance for undertaking reviews in healthcare (see Appendix 1). One reviewer extracted data from the included studies for this review under the guidance of the supervisor (in line with PhD regulations). The data from included studies were critically questioned and examined by supervisors and any relevant aspect if missing was discussed. One important discussion was the age category; the inclusion criteria were 65 years and over, and hence it was decided that studies with this age group were included. Therefore, during the process of data extraction, studies that included younger ages but also provided separate analysis on older people aged 65 years and above were deemed appropriate for data extraction for that age group.

General information and study design

Information regarding study ID, title, type of publication, author's names, year and country were extracted. Information on the study methodology, design, aims and objectives, selection criteria and recruitment procedures for the study sample was also extracted.

Participant information

Information regarding type, age or age range, gender, ethnicity, and number of participants were extracted from the included studies. The centre or organisation from which these participants were recruited was also reported in the data extraction form. The sample population's socio-economic or education status, health and disease characteristics were all obtained.

Exposure characteristics

Information regarding the exposure or independent variable was extracted; the definition, or measures used to define the variables, was obtained for the form. The form also reported any standard questionnaire, or other tools used by the study to measure its study participant's exposure.

Outcome characteristics

Information regarding the definition of the outcome, standard measures used, or any measurement tool or instrument used to report the outcome was extracted. If the outcome was more than one type, or had sub-types, all were reported in the table accompanied by their definitions.

Statistical analyses, results and conclusions

The form also extracted information regarding the statistical tests done (for example regressions, *t*-tests), covariates and their confounding actions adjusted and controlled for, direction and magnitude of associations, and conclusions made by each of the included studies.

4.3.6.3 Assessment of risk of bias in included studies

In addition to data extraction, a risk of bias assessment was carried out for the included studies. Bias here refers to, "systematic deviations from true underlying effects brought about by poor study design or conduct in collection, analysis, interpretation, publication or review of data" (CRD, 2009). There can be bias in data based on limitations in the design or conduct of the included studies. To ensure reliable estimates of the review question, it is important to distinguish between studies that have a possibility of bias from those that do not (Denison *et al*., 2013). Differences in the risk of bias between included studies can explain differences in their findings (CRD, 2009).

The assessment of risk of bias in the included studies was done alongside the data extraction process using the tool provided in the Cochrane Handbook for Systematic Reviews (Higgins 2011). Five main types of biases were assessed namely, selection bias, measurement bias, classification bias, attrition bias and reporting bias. The different levels of risks of biases were low, high and unclear following the criteria given by the Cochrane Handbook of Systematic Reviews (Higgins, 2011). The risk of bias tool is a set of questions adapted from the Cochrane collaboration data extraction form, which is attached in the appendix (see Appendix 2). These questions focussed on selection bias by assessing the included study's target population, its representativeness, and the random selection procedure. It also assessed the included study's response rate to gauge any attrition bias. The definitions, classification and instruments used for measuring the outcome and exposure and the level of validity of these measurements were assessed to estimate the measurement bias.

4.3.6.4 Quality of included studies

The quality assessment of the included studies is often undertaken at the same time or follows closely after data extraction from the included studies. For this review, the quality of included studies was checked against a standardised checklist for critical appraisal, which tested the quality and validity of the design and results of studies. The Critical Appraisals for Skills Programme (CASP) checklist was used to appraise the included papers for this review (www.casp-uk.net). It is attached in the appendix (see Appendix 3). The three questions that the CASP checklist explored were, a) whether the results were valid, b) what were the results, and c) would they be applied locally. Below is a brief explanation of the CASP checklist that was applied on each of the included studies of this review.

Were the results of the included study valid?

To determine the above, aspects of the included studies were inspected such as whether the study addressed a clearly focussed question, was the cohort selected appropriately, were the exposure and outcomes measured accurately, were the confounders identified and accounted for in the analysis and was the follow-up complete.

What were the results of each included study?

This was determined by focussing on the statistical analyses conducted, results demonstrated and tabulated and explained in text for each independent and dependent variable. Whether the result statistics included the degree of associations made between independent and dependent variables, odds ratios/risk ratios, means, standard deviations, standard errors, confidence intervals and *p*-values.

Can the results of the included study be generalised to local population*?*

This was determined by looking at the external validity, and generalisability of the results; whether results fit with the other evidence or not.

4.3.7 Data analysis and synthesis

After data extraction, risk of bias and quality assessment, the next step was to analyse and synthesise data. Data analysis consisted of examining strategies for dealing with the results of the individual studies with one or more exposure and/or outcome variables, handling the missing data, different study designs, different follow-up period, different choice of effect measures, exploring a common trend across studies based on either its exposure-outcome relationship, inspecting data for the choice of methods required to synthesise the data, and examining the studies for the choice of quantitative or qualitative synthesis, etc.

The results of the included studies could be presented qualitatively or quantitatively. Qualitatively, the results were supposed to be presented in a tabular form and described narratively, where the results of the included studies of similar study design, similar exposure and outcome measures and common trend in the association between exposure-outcome, were to be grouped together. It was planned to conduct a meta-analysis for quantitative synthesis of data where possible if the data across the included studies were homogeneous. For the same reason the studies were examined for variability in data and reported result statistics; this checked for the presence of heterogeneity of any kind in the included studies of the review (Higgins 2011).

4.4 RESULTS

The following section describes, in detail, the results of this review. It includes the results of the searches conducted, the results of the process of selecting studies, the reasons for excluding studies, and the characteristics, risk of bias, and the methodological quality of included studies and finally, the data synthesis and the relationship demonstrated between exposure (social factors) and outcome (pain) variables of the overall review findings.

4.4.1 Selection of studies

The PRISMA flow chart (Moher *et al*., 2009) presents the results of the screening and selection process that was applied for the selection of studies (refer to Figure 4.1). A total of 3258 articles were retrieved through the initial search and after removing duplicates 2783 records remained. These 2783 records were then imported via the Mendeley web importer of the Mendeley Reference Manager for further shortlisting. During the initial screening of article titles, many duplicates that still existed were discarded from the Mendeley library; further on after applying the eligibility criteria (reading titles as well as abstracts), a total of 2759 studies were not relevant for the current study’s research question and hence were removed. These papers were classified as not relevant as they did not focus on the study’s research question, rather their focus were on issues such as: institutionalised patients in pain, post-surgical pain, studies on labour pain, participants with cancer pain or terminally ill patients in pain, geriatric depression, cognitive impairment, dementia, physical disability, fractures, health related QOL, overviews of pain and pain management, younger/middle aged adults, pain in care workers, effects or correlates of social support and social vulnerability in older adults, social interactions at work, pain as a predictor for depression in older people, a couple of reviews and conceptual papers, amongst others. After this initial screening, only 24 potentially relevant papers remained. The full texts of all of these papers except one were obtained, and after applying the selection criteria a further 15 studies were excluded with reasons (refer to table 4.3). Nine studies remained, which were included in this review because they met the inclusion criteria.

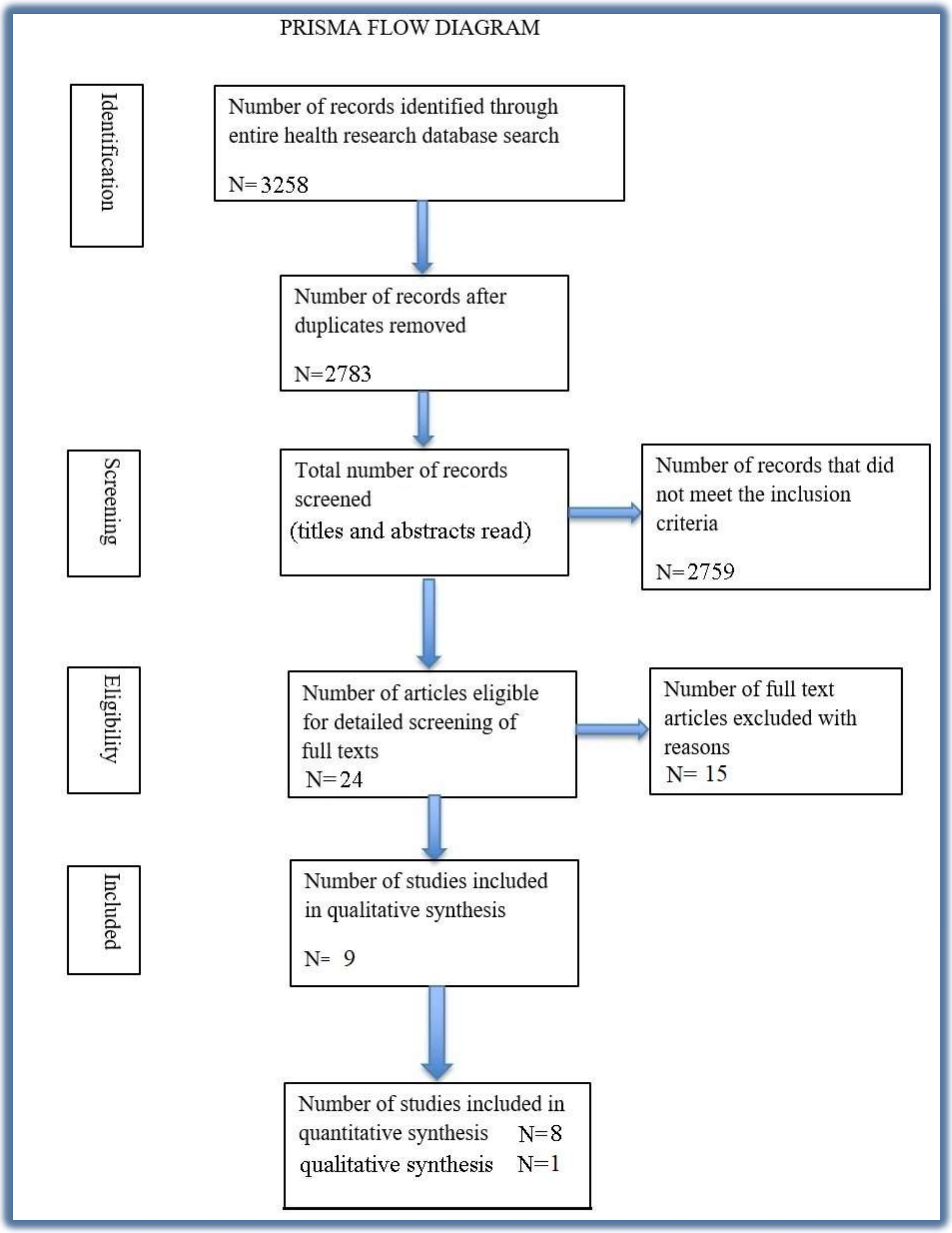

*Figure 4. 1 PRISMA flow diagram (*Moher *et al.,* 2009)- The PRISMA flowchart representing the results of screening and selection process for the included studies. Identification stage resulted in N=2783 studies after removal of duplicates. Screening stage (reading titles and abstracts) resulted in removal of further N=2759 studies. Eligibility stage shortlisted N=24 studies for full text details. Included studies stage resulted in a total of N=9 studies.

4.4.2 Excluded studies

A total of fifteen studies were excluded from this review after reading the full texts and applying eligibility criteria. These studies were tabulated (refer to table 4.3) with reasons for exclusion.

Table 4. 2 List of excluded studies with reasons for exclusion (Chronological order)

Excluded study	Reasons for exclusion
1. Weinberger *et al*., 1986	*Exposure variable was formally administered social suppor) and hence different to the one in current study.* This study focused on patients with osteoarthritis and hypothesised that telephonic interviews from staffs/data collector of the research organisation would provide patients with social support and help improve their functional status.
2. Jamison and Verts 1990	*The study population and age group was different when compared to the current study.* This study focussed on adult patients with chronic pain and the perceived role of family support on their pain behaviours. Participants were divided in to groups of families with a) support and b) disharmony.
3. Blixen and Kippes (1999)	*The outcome variable was different to the one in the current study.* The study focussed on assessing the quality of life outcome in older adults with osteoarthritis suffering from various levels of depression and social support. This study was conducted with an aim to manage the functional status, pain and overall quality of life of older adults and guide and outline nursing interventions.
4. Jakobsson *et al*., 2003	*The aim of the study and the study population were different when compared to the current study.* The study focussed on participants aged 75 and older in sheltered

	housings or having some home care help for daily living, and divided them in two groups of those with pain and those without. It investigated the prevalence of pain and compared the two groups in regards to their demographics, social networks, functional status, sleeping problems, depressed mood and quality of life.
5. Jakobsson *et al*., 2004	*The research aim and the outcome variable (pain management strategies) were both different even though some aspects of the exposure variable were similar.* This study focussed on older people between 76-100 years of age living alone, with someone or in special accommodations with chronic pain and it investigated their pain relieving, management methods used to overcome or assist in their activities of daily living.
6. Mavandadi *et al*., 2007	*Both exposure and outcome variables were different to the one in the current study.* This study focussed on older people's baseline pain and how it influence the positive and negative social exchanges over time. It also investigated the role of these exchanges in accounting for the association between pain and depressive symptoms in older adults.
7. Luger *et al*., 2009	*Outcome variable was different to the one in the current study.* The study focussed on older adults with osteoarthritis and physical disability, and aimed to investigate the influence of psychosocial factors (dispositional personality and social relationships) on their life's satisfaction and well-being.
8. Matos and Bernardes (2013)	*Exposure variable was different to the one in the current study.* The study focussed on participants between 56-90 years of age who attended a day care, nursing home, and senior university. The study aimed to develop and preliminarily investigate the validity of the Portuguese measure of perceived formal social support for autonomy and dependence in pain inventory.

9. Matos *et al*., 2016	*Exposure variable was different to the one in the current study.* The study focussed on participants aged 50 years and above who attended a day care centre with formal social support provided from staffs at the organisation. The extent to which self reported physical functioning mediated the relationship between perceived promotion of autonomy/dependence and pain related disability was investigated.
10. Riffin *et al*., 2016	*The research aim was different even though some aspects of exposure and outcome variables were similar.* This qualitative study focussed on population aged 60 years and over who attended a senior centre and the role of social networks both formal (physicians, nurses) and informal (others with similar conditions, family or friends) on decision making of MSK pain management.
11. Matos *et al*., 2017 (Journal of Pain)	*Exposure variable was different to the one in the current study.* The study focussed on participants aged 50 years and above who attended a day care centre with formal social support provided from staffs at the organisation. The variable of formal social support was investigated to evaluate direct effects of support on functional autonomy and dependence on pain related disability, efficacy and fear.
12. Matos *et al*., 2017 (Journal of Health Psychology)	*Exposure variable was different to the one in the current study.* This study focussed on participants aged 50 years and above who attended a day care centre with formal social support provided from staffs at the organisation. The variable of social aspect under investigation was perceived frequency of formal social support (from staff and nurses at the day care) for autonomy and dependence- a buffer or amplifier of pain.
13. Hay *et al*., 2019	*Exposure variable was unclear in the abstract provided and could not get access to full text even after doing the needful.* This study tried to explore how older adults lived pain free in their

	bodies by incorporating physical exercises in their lives.
14. Smith *et al.*, 2019	*Outcome variable was not the same as for the current study.* This study focussed on associations between MSK pain with social isolation and loneliness in non-institutionalised population of individuals aged 50 years and above. Pain was a predictor variable for wider health implications and study outcomes were social isolation and loneliness.
15. Nicolson *et al.*, 2020	*Outcome variable was not the same as for the current study.* This study focussed on social implications of MSK pain in community dwelling older adults aged 65 years and older. Pain was a predictor variable for study outcomes that included loneliness, social support and social engagements.

4.4.3 Data extracted from included studies

The included studies from which data was extracted are tabulated below with important information on each of their characteristics (see table 4.4).

Table 4. 3 Included studies and their characteristics (chronological order)

Study (design & country)	Sample/age & size	Exposures	Outcomes	Conclusion
1. Weinberger *et al.*, 1990 Cross sectional USA	Participants belonged to a town in the USA, registered to a General Medicine Practice with a mean age of 62 years. Sample size 439.	Interpersonal support Evaluation List (ISEL) consisting of support measures such as esteem, tangible, belonging, appraisal.	Arthritis Impact Measurement Scales (AIMS) comprising of three functional dimensions namely, physical disability, psychological disability and pain outcome.	Analyses were conducted separately for each AIMS dimensions. The only significant associations were between social support and psychological disability. The association with pain outcome was

				not significant.
2. Peat *et al.*, 2004 Cross sectional England	Population based prospective community living cohort. 50 years and older (separate data for pain prevalence available for 70 years and over). Sample size 5215.	Structural social network; marital status, number and frequency of contact with the social ties (children, relatives, close friends, confidant).	Pain related interference with daily activities. Responses were dichotomised. None/mild and moderate/extreme.	Significant association found between people seeing friends more frequently and lower pain interference with daily activities.
3. Weismann *et al.*, 2014 Cross sectional Germany	Participants belonged to a small town in northeast Germany, living in the community aged 57-96 years (mean age=73.8 years) Sample size 387	Sense of coherence and psychological resistance resources (self-esteem, self efficacy, optimism, and social support), along with morbidity scores.	Bodily Pain subscale of the SF-36 Health Survey assessed pain intensity and interference. How much bodily pain & interference with normal work have you had during the last four weeks	Sense of coherence was predictor of bodily pain, and it acted as mediator in pooling resistance/deficits influence on pain.

4. Leung *et al.*, 2015 Longitudinal Singapore	Community dwelling prospective cohort. 60 years and older. 3103 older adults were included in analyses at both points in time (baseline and follow-up).	Structural social network size, frequency of contact, closeness, and perceived support from friends and relatives outside of the household. Social activity assessed by frequency and number of activities attended.	Pain onset and progression From a sample that had no pain at baseline, those who reported no pain at the second time-point were categorized as not having pain onset (0), whereas those who reported mild-moderate to severe pain at the second time-point were categorized as having pain onset (1).	Study findings provide evidence that an association exists between chronic pain and living styles and social network and might have an implication on building strong social support both within and outside the household.
5. Richardson *et al.*, 2015 Longitudinal England	Mixed methods study where participants belonged to longitudinal cohort study (NorStOP) aged 50 years and over. 226 participants were called for an interview.	Social activity, physical activity and involvement. Social network was important measure in maintaining physical activity as it provided incentives for a walk, any sport, golf, or shopping.	Pain interference was the outcome measure under investigation.	Results of showed that key to living well with chronic pain was being physically and socially active, and involved in life, while maintaining a flexible attitude and willingness to adapt activities.

6. Lee *et al.*, 2016 Longitudinal USA	The study focussed on retired community dwelling 299 residents aged 72 years and older diagnosed with arthritis pain.	The exposure variable under investigation was psychological resources such as social support and intact cognitive functioning. Analyses for social support was presented separately.	The outcome was arthritis pain and depressive symptoms. Analyses for both outcomes separately were presented.	Better cognitive functions predicted lower pain levels. After controlling for pain, those with higher cognitive functions and social support showed lesser depressive symptoms.
7. Hung *et al.*, 2017 Cross sectional USA	Participant data was obtained from 2012 Health and Retirement Study (HRS). Age 65 years and older, sample size 2411.	Exposure variable under investigation was measure of social support scale structured such that it has in total seven items with three positive and four negative subdomains	Pain was self-reported and measured with an initial question, 'Are you often troubled with pain? For those answering yes, intensity was further measured as (mild, moderate, severe).	Findings suggested that support measure lowered depression, however no association was found between overall social support from family and pain.

8. Musich *et al.,* 2019 Cross sectional USA	Participants comprised of a national survey respondents of health insurance companies including older adults aged 65 years and over. Sample size 4161.	Positive attributes (social network and resilience) Negative attributes (depression, stress, poor sleep) Social Network Index- counts contacts across four types of support from (family, friends, religious, and leisure organisations).	Pain severity and pain interference were assessed using the validated 3-item PEG (pain severity, interference with Enjoyment, interference with General activity) assessment on 0-10 scale.	Medium, and diverse social networks and high resilience reduced likelihood of severe pain severity and interference. In fully adjusted models, the negative attributes maintained strongest associations with severe pain severity and interference.
9. Mallon *et al.,* 2021 Longitudinal Germany	Participants belonged to a prospective, observational cohort study living in community aged between 65-85 years of age. Sample size 1865.	Depressive symptoms and general perceived social support (German scale) were exposure variables. The scale measured emotional and instrumental support, and social integration.	Outcomes were measured as pain intensity and pain related disability in daily activities and subscales of Graded Chronic Pain Scale (GCPS) was used	Perceived social support interestingly increased the association of depressive symptoms on pain intensity and did not show a protective role.

4.4.4 Detailed description of included studies

Weinberger *et al.* (1990) identified their potential subjects from a computerised medical record system in the GMP care in a town in US. A sample of 587 older people met the study criteria, out of which 439 agreed to participate (75% response rate). Non-responders were comparable with respect to age, race, and sex but functional status comparisons could not be made based on the data in computerised medical record system. The relationship among social support (tangible, appraisal, self-esteem, belonging), stress and functional status (psychological disability, physical disability and pain) was investigated in older adults with arthritis. Findings indicated that more than 80% were female participants; being older, having less education and income were univariately associated with physical disability. Findings demonstrated that univariately the dimensions of social support were related to physical and psychological disability only ($p \leq 0.01$). Pain was only related to self-esteem ($p \leq 0.001$) and tangible support ($p \leq 0.05$) univariately. In the final regression analyses after controlling for the demographics and stress variable, social support and functional status (particularly pain dimension) were not significantly associated for this dataset.

Peat *et al.* (2004) demonstrated a relationship between the structural aspect of social networks (ties, its number and type) and pain related interference and impact on daily activities. This study was conducted on participants' ≥50 years in North Staffordshire (England). Structural social network included information on the number of living children, close friends, close relatives, and the number of each with whom they contacted within the previous month, also the presence of a confidant and frequency of contact with their confidant. Demographically the dataset consisted of more than 50% of female participants, who reported pain interference with increasing age. Results showed that pain interference with daily activities increased with age, a trend most marked in women being highest in those aged 80 and above. Associations between individual social network variables and pain interference with daily activities separately for men and women adjusted for age were reported. For both men and women, the presence of confidant showed little relationship with pain interference, however, being widowed for both men (OR=1.3) and women (OR=1.25), was significantly associated with higher pain interference with daily activities even after adjusting for age. Study findings overall indicated that participants with few or no social ties experienced pain that interfered with daily activities. However, this effect was reversed with men participants who reported having children. After adjusting for age in men (OR=0.8), those with more living children were significantly more likely to experience pain interference with daily living. Furthermore for all participants, both the absence of close friends (OR=2.19) and the lower frequency of contact (OR= 1.37) or no contact with friends (OR= 2.24) were significantly associated with higher pain interference; however only women (OR= 1.27) showed a strong significant association between absence of close relatives and higher pain interference. However, in multivariate analyses, after adjusting for socio-demographics, comorbidity, and depression, the only significant association remained was between being-widowed and pain interference with daily activities. In addition to this, another significant association demonstrated was men with three or more children showing more pain interference with daily activities even in multivariate analysis.

Weismann *et al.* (2014) recruited participants for their study (distributing 600 questionnaires) through sports clubs and social clubs in a small town in northeast Germany. The final sample consisted of 387 older adults, predominantly women (73%). Older persons with dementia, geriatric cognitive disorders and those critically ill or undergoing in-patient treatment were not eligible. The study investigated the relative contributions of three sets of independent variables on the outcome of bodily pain. These exposures included chronic morbidity, psychological coping resources (self-esteem, self-efficacy, optimism, social support), and sense of coherence. Findings indicated that all psychological resistance resources and morbidity were significantly associated with sense of coherence and pain ($p \leq 0.01$). However, social support and pain were not significantly related. Multiple hierarchical regressions were conducted to determine the relative roles of predictor variables on pain; model 1 revealed that morbidity was a strong predictor for pain ($R^2=0.21$, $p \leq 0.001$). On entering the psychological resources in model 2, accounted for additional variance; and in model 3, on entering the sense of coherence variance increased further but it made the significant effect of self-esteem from model 2 insignificant. Hence we then entered the psychological resources in model 3, so as to determine their effect on pain prediction. This time it did not account for any additional variance. Overall analyses indicated that morbidity and sense of coherence were important pain predictors.

Leung *et al.* (2015) used prospective data from a nationally representative longitudinal study survey of community-dwelling Singaporeans aged ≥60 years to evaluate the relationship between living arrangements, social networks and onset and progression of chronic pain over a period of two years. The weighted response rate was 63.7%. Pain onset and progression were the two outcomes under investigation in this study. Luben's revised social network scale for structural social network (size and frequency of contacts with friends and relatives outside household, closeness, perceived support) and social activities outside household was measured as exposure variable and onset and progression of pain as outcome. Demographically women formed a little more than 50% of the sample population, being women older were significantly associated with pain outcome. The study's main findings were; living with more people had a strong negative association with onset of chronic pain among women (OR= 0.42, p≤0.001) even after adjusting for the confounding factors (socio-demographic factors) in binomial logistic regression models. A similar trend was observed for the progression of chronic pain but was not statistically significant. In contrast, weak social networks outside of the household were significantly associated with the progression of chronic pain among women (OR= 1.57, p≤0.01); and this was true even for the onset of chronic pain.

Richardson *et al.* (2015) used data from the original longitudinal cohort study (North Staffordshire Osteoarthritis Project- NorSTOP) conducted in the UK on people aged 50 and above. The outcome variable under investigation was pain that interferes with everyday activities. Qualitative interviews were conducted on a selected sample recruited by a method of maximum variation sample of 226 participants who belonged to three pain groups (1) those with no pain, 2) those with pain and interference in daily activities, 3) and those with pain but no interference in daily activities). For this study, the group with pain and no interference was of special interest since the study aimed to explore, *'living well with chronic pain in later life'*. This study however, integrated a mix of qualitative and quantitative data analyses to find answers to how people with pain manage to reduce its impact in later life. The theme generated from the interview in phase-1 with three groups was similar for those with no pain and those with pain and no interference, *'being socially and physically active and involved on an everyday basis'*. Therefore, group-3 was further explored and in phase-2 qualitative data was analysed with quantitative data (gathered on this population in the original NorSTOP) to compare their demographics, socio-economic conditions, comorbidities etc. and pain levels. For all these participants in group-3 pain status was moderate to severe (something that was determined earlier on while selecting the sample (226) to interview for pain related study from among the original study sample). However based on other socio-demographic and health comorbidity factors, those expected to be living well with pain and those not expected to be living well with pain in this group were qualitatively analysed and the findings indicated that for these people managing to live well with pain, is not simply because of their pain being less severe, nor their socio-economic status being high or having less comorbidities; it was because they had a common understanding of being physically and socially active within their capabilities, maintaining flexible attitudes, being involved in life and willingness to adapt to activates.

Lee *et al.* (2016) conducted a longitudinal study on 299 older adult residents living in the community in US. This study tried to explore the role of social support and intact cognitive functions on pain and depressive symptoms. Arthritis pain was assessed by an AIMS2 (subscale of Arthritis Impact Measurement Scale), which included items about severity of pain, morning stiffness and sleeplessness due to AR. Tangible support was assessed with the social support scale developed by the co-authors of the study. Question asked was, ‘how much help did you receive from family, friends and neighbour in the area of cooking, transportation, during sickness aid, and personal help. The multilevel linear mixed modeling was conducted since it helps to analyse change using longitudinal data by making use of all available data from individual emphasising on individual trajectories rather than average values. The results showed that individuals with better cognitive functions reported lower arthritis pain ($\beta=-0.23$, $p\leq0.01$), and effect of social support on between-person means was also significant ($\beta=0.40$, $p\leq0.01$), but no effect on residual variance. This indicated that individuals with better cognitive functions and lower social support reported lower levels of overall pain symptoms. Hence concluding that cognitive functioning had a significant negative linear effect on depressive symptoms and arthritis pain, but social support had a negative linear effect on arthritis pain only.

Hung *et al.* (2017) used the data obtained from the 2012 HRS (Health and Retirement Study) that included a study sample of 2411 people aged 65 years and older. They investigated the role of family support on pain and depression in participants with arthritis. The outcome variable was self-reported pain with an initial question, *'are you often troubled with pain?'* if the answer was yes, then those respondents were further asked about its severity- mild, moderate, severe. The family support (exposure) was measured using a social support scale structured for HRS based on a reliable scale developed and used by previous studies. Demographically the sample consisted of 65% of female population; being older was associated with pain outcome. The logistic regression results showed that although pain decreased as support levels (from spouse, children, other family member) increased on crude associations; but after adjusting for covariates (age, education, marital status, functional status, high health status and medication) this association was not significant. However even after adjusting for covariates, depressive symptoms decreased significantly with strong support from spouse ($p<0.05$).

Musich *et al.* (2019) conducted a study survey to find associations of resilience and social networks with pain outcome among older adults aged 65 and older. This survey conducted by an insurance company in the US generated a stratified sample mailing list and after applying the inclusion criteria, the final study sample included 4161 survey respondents. The response rate was low at 29%, therefore, the responses were weighted to adjust for non-response bias and to be representative for those with pain conditions. The outcome measure was a validated 3-item pain scale, which measured pain severity (P), interference with enjoyment (E), interference with general activity (G). Both resilience (6-item Brief Resilience Scale) and social network index (counts across four types of social connectedness: relationship with family, friends, and visiting religious, leisure organisations) were measured using the scales developed as well as used in earlier studies. Demographically the sample had a larger representation of female survey respondents; being female was associated with pain severity and interference both. Also, both pain outcomes were most prevalent in age group 70-74 years. Findings of bivariate regression analyses indicated the protective role of both high resilience and medium-diverse social networks on pain severity (0R=0.3 to 0.7) and pain interference (OR=0.2 to 0.7) outcomes. However, the variable most strongly associated on bivariate regressions was depression with both pain severity (OR=4.1 to 9.4) and interference (OR=4.5 to 13.3); and stress with both pain severity (OR=5.0 to 9.2) and interference (OR=5.4 to 12.2). Second most associated characteristic with pain severity and interference was sleep deprivation. In fully adjusted models, both depression and stress was attenuated by 40-50% and poor sleep by 20-30%) after controlling for high resilience and moderate to diverse social networks. It showed that both high resilience and medium/diverse social networks reduced the likelihood of moderate to severe pain (both severity and interference). All the above results of associations were significant ($p \leq 0.0001$).

Mallon *et al.* (2021) randomly selected participants for their study on the moderating effects of social support and depressive symptoms on pain outcome among the older adult multi-morbid patients living in the community from a prospective observational longitudinal study through GP recruitment across eight cities in Germany (MultiCare). This study randomly selected participants for interview and shortlisted a total of 3189 older adults based on their inclusion criteria. However, over the follow-up period of five years, when participants were called for interviews at three time points; loss occurred due to deaths, inability to contact, worsened health conditions, and missing data from the GP. Final sample size consisted of 1865. Outcome measure of pain intensity and pain related disability was investigated under the influence of social support (emotional, instrumental, social integration). Majority of this sample population were females (60%). The pain intensity score was associated with an increase in age. However, the study findings contradicted study hypothesis indicating significant positive interaction (interaction analyses) between social support and pain intensity (but not significant for pain disability). This meant that higher scores of perceived social support influences relationship between depressive symptoms and pain intensity resulting in higher pain intensity scores. The results from linear mixed-effects analyses adjusted for random effects demonstrated an estimate=0.41 (SE=0.17, 95% CI, $p \leq 0.01$). The study findings are new as they point towards an apparent negative aspect of perceived social support for this dataset.

4.4.5 Risk of bias in included studies

The following is a detailed description of the risk of bias for all included studies based on the domains discussed in the methodology section for risk of bias (refer to subheading 4.3.6.3). Table 4.5 outlines the various risks of bias, and their respective level of bias. In addition to this, a risk of bias graph has been represented as percentages across all studies (refer to figure 4.2) to examine the overall risk of bias.

Table 4. 4 Risk of bias assessment for included studies (chronological order)

Included study	Type of bias assessed	Description from the study for evidence	Level of bias risk
1. Weinberger *et al*., 1990	Selection bias	Strict and narrow selection criteria to shortlist participants. People who volunteered to take part and were selected were paid incentives. Study had a longitudinal aspect to it, so those with likelihood of survival for the next year were only selected. Non-participants could not be completely accounted for in respect to comparability to functional status because of the way data was stored in the computerised medical record system.	High
	Measurement and classification bias	The Arthritis Impact Measurement Scale was used to asses functional status (physical disability, psychological disability, and pain). For OA, in absence of any disease activity self reported measure is acceptable. OA patients have demonstrated high correlations between AIMS and Sickness Impact Profile (which is a well validated widely used measure of quality of life).	Low
		Interpersonal Support Evaluation List (ISEL) scale for social support (tangible, appraisal, esteem, and belonging) was used and is a validated scale.	Low
	Attrition bias	Not reported	Unclear

	Reporting bias	The study has reported its findings critically also highlighting the implications of measurement scales and raising the caveats of the study in respect to its design and sample population.	Low
2. Peat *et al*., 2004	Selection bias	Population based prospective cohort. Sample was drawn from baseline self-complete Health Survey questionnaires sent to all adults aged 50 years and over registered with the three participating practices in North Staffordshire. Survey respondents as a whole were very similar in general health, age, gender, and marital status to UK norms.	Low
	Measurement and classification bias	Pain prevalence was described by single item SF-12 questionnaire.	Low
		Social network: Items originally described by Berkman and Syme (1979) was used in this study that captured self-reported information on the number of living children, close friends, and close relatives, confidante, etc.	Low
	Attrition bias	High response rates.	Low
	Reporting bias	Study reported limitations such as lacking generalisability and was dependent on a brief self-report measure for structural social network.	Low
3. Weismann *et al*. 2014	Selection bias	Findings were limited to cross-sectional nature of data and sample was a fairly healthy (excluded dementia and cognitive impairment conditions) convenience sample (600 questionnaires were handed out in social, sports clubs in	High

		a small town in Germany).	
	Measurement and classification bias	Pain was assessed by SF-36 Bodily Pain measure and not by a standardised pain inventory scale which also includes a disability measure. It was also reported as a limitation in the study.	High
		Expected social support scale, self-efficacy scale, self-esteem scale and optimism score and validated scale for sense of coherence was used to assess exposure variables. All of them were validated from and used in earlier studies.	Low
	Attrition bias	Not reported	Unclear
	Reporting bias	The study has clearly reported its limitations (about study design, very narrow and healthy sample population, selection criteria of the sample, pain assessment measure etc.)	Low
4. Leung *et al.*, 2015	Selection bias	Nationally representative large sample size, stratified by sex and ethnicity	Low
	Measurement and classification bias	Participants were asked to respond to the question: "Overall, in the past 30 days, how much of bodily aches or pains did you have (none, mild, moderate, severe and extreme)?"	Low
		Lubben's revised social network scale to assess the social networks of the respondents outside the household was used. The scale consisted of 12 items (six for social networks with friends and six for social networks with relatives outside the household) assessing the size	Low

		of network, frequency of contact, closeness, and perceived support from friends and relatives outside of the household. The degree of involvement in social activities was assessed through its frequency, and number of activities attended (attending activities in the community, neighborhood or places of worship.	
	Attrition bias	Response rates obtained in the study was higher than for usual surveys.	Low
	Reporting bias	Limitations of the study were reported clearly.	Low
5. Richardson *et al*., 2015	Selection bias	Qualitative study with a nationally representative longitudinal cohort sample. Maximum variation sample chosen.	Low
	Measurement and classification bias	Topic guides, Lifegrids, Health events sheet were used to guide the interview sessions. Pilot interviews were conducted to help refine interview tools. Final in-depth interviews were digitally recoded, professionally transcribed, checked and anonymised.	Low
	Attrition bias	Not reported	Unclear
	Reporting bias	The study reported its weakness about the survey question regarding pain interference misjudged by respondents as they adjust to activities	Low

6. Lee *et al*., 2016	Selection bias	They followed a set of pre-defined strict selection criteria and participants were selected from a large, age-segregated, older adult community located in central Florida, living on their own. Out of around 5000plus residents, a sample population of 1000 was interviewed at baseline and then on subsequent follow-ups. After four years of follow-up and attrition, a sample of 299 remained.	Low
	Measurement and classification bias	Internal consistency and reliability of the outcome measurement was very good.	Low
		Internal consistency and reliability of exposure measurement was good.	Low
	Attrition bias	Participants were lost due to deaths in the follow-up. 7% of attrition yearly in a four-year follow-up study.	Low
	Reporting bias	Limitations were reported for sample size, characteristics of the sample population, attrition rate, etc.	Low
7. Hung *et al*., 2017	Selection bias	Nationally representative large sample obtained from the Health and Retirement Study (HRS).	Low
	Measurement and classification bias	Pain was self-reported and measured with an initial question, ‘are you often troubled with pain?’ for those who answered, ‘No’, it was marked as no pain response. This could have led to under-reporting of pain, also mentioned in study limitations. Also since it's a self-report measure it has not been widely studied in terms of psychometric properties. However, this measure of	High

		pain had been used in previous studies and found to be prompt in clinical responsiveness recommended by AGS guidelines for management of persistent pain.	
		Social support scale exhibits reliable psychometrics and has been used in earlier studies too.	Low
	Attrition bias	After applying the inclusion criteria of age (65 and older) and presence of arthritis, reporting of pain and depressive symptoms, 2411 older adults were selected for the study sample. Response rate is not specifically mentioned in the paper, and since it is a cross-sectional design, it is assumed that there was no attrition bias.	Low
	Reporting bias	Limitations of the study are clearly reported (cross sectional design, sample of Caucasians and African Americans majorly and very small number of other races, results only applied specific to national population etc.)	Low
8. Musich *et al*., 2019	Selection bias	Stratified sample mailing list was selected for a pain-related survey. Response rate was as low as 29%, however it was weighted to adjust for non-response bias, to be representative of those with these pain condition. Propensity weighting analyses were conducted for enhancing generalisability and adjusting for selection bias.	Low
	Measurement	Pain was measured using validated PEG	Low

	and classification bias	scoring; assessing the **p**ain severity (P), interference with **e**njoyment (E), and interference with **g**eneral activity (G)	
		Aung *et al*., 2006 study was used as a guideline to score the social network of the participants in this study as mentioned. Social network index counted four different types of social connectedness from family, friend, religious, and leisure organisation.	Low
	Attrition bias	Response rate was as low as 29% as mentioned in the study.	High
	Reporting bias	Limitations were not very clearly mentioned and outlined covering all the aspects of the study. One of the authors was an employee of the insurance organisation conducting this survey.	High
9. Mallon *et al*., 2021	Selection bias	Patients with dementia were excluded, those who had less than three morbidity conditions were excluded, and the study data were collected over five-year period hence survivor bias would have occurred due to dropouts.	High
	Measurement and classification bias	Pain intensity and pain related disability was measured using the Graded Chronic Pain Scale (GCPS), used in earlier studies and had guideline and procedural manual to use during patient interviews.	Low
		Self-reported social support was measured using the German scale. It did not include social network size or distinguish between emotional, instrumental or informational support.	High

	Attrition bias	After applying all inclusion exclusion criteria to among a random selection of 24862 patients, 3189 were included in the study. However, final sample size came up to 1865 due to drop-outs, loss to follow-up, inability to contact etc.; and dropout was reported as 41.5%.	High
	Reporting bias	Limitations of the study were clearly reported (such as restricted generalisability, dropouts and sample attritions, self-report social support measure etc.)	Low

The risk of bias graph reveals that the majority of the studies had a low risk of selection and measurement bias. However, attrition bias was unclear to high risk for more than half of the studies included in this review. This points towards issues with dropouts and loss to follow-up in the sample population of the studies. Subsequently, this has resulted in overall lowered generalisability of results due to the sample population after attrition not exactly representing the target population.

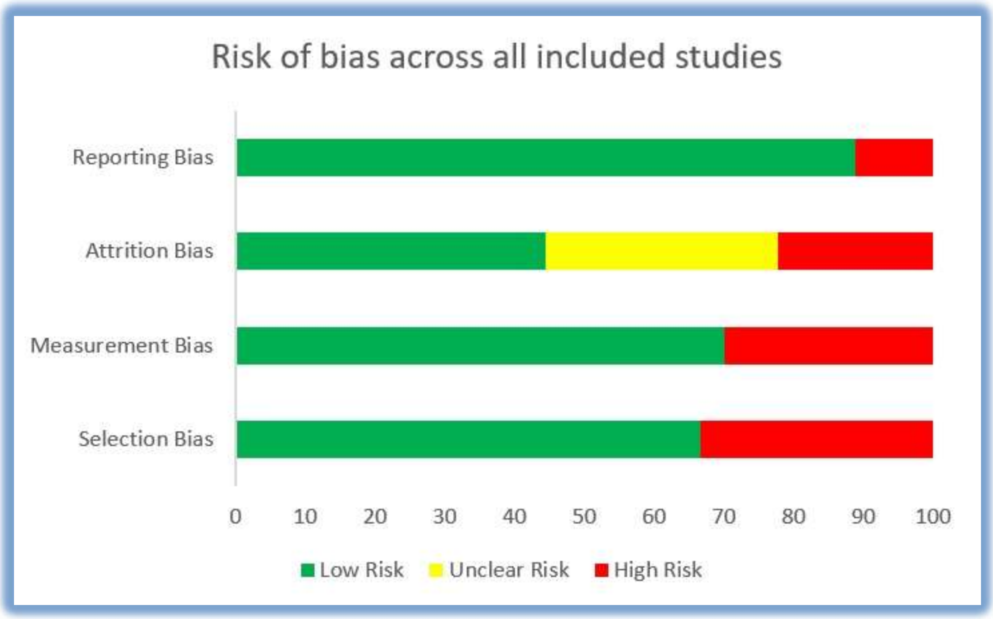

Figure 4. 2 Risk of bias graph: each risk of bias presented as percentages across all included studies- Risk of bias across all included studies depicted a low risk of bias

for selection (>60%) measurement (>70%) and reporting (>90%) biases, with the exception of attrition bias demonstrating more than 50% of unclear to high risk of bias.

4.4.6 Quality of included studies

Following is a detailed description of the quality assessment for all included studies. Table 4.6 outlines the various questions and their judgements or answers, for each included study individually. In addition to this, a graph assessing the overall quality of studies in this review has been represented as percentages (refer to figure 4.3).

Table 4. 5 Quality assessment CASP checklist results

Author's name	*Are the results valid for the research question in hand?*	*What are the results in relation to the current research question?*	*Can these results be applied locally?*
1. Weinberger *et al*., 1990	No This study aimed to explore the relationships among social support, stress and functional status of patients with arthritis. Both exposures (perceived social support and outcome (physical disability, psychological disability and bodily pain) were classified as a part of other predictor factors. But the analyses results for separate predictors were reported by the study, hence it was included.	The pain dimension of the Arthritis Impact Measurement Scale was not significantly associated with any of the support subdomains. The only significant associations were between social support and psychological disability.	No Very small sample size, belonged to a town in the USA obtained from a GM practice, predominantly Black and more than 80% women, and low SEP.

2. Peat *et al*., 2004	Yes The study addressed a clearly focused issue in terms of its population. The outcome considered was pain interference with daily activities. The study defined its exposure variable as structural social network. The sample was selected by a survey in the north Staffordshire region of England. Respondents of the survey were as a whole very similar to UK norms. Both exposure and outcome variables were defined using standard measures which are evidenced in literature. The confounding factors were identified and controlled for in the analyses while making associations.	The results of the analyses demonstrated that the presence of, and frequency of contact with, a confidant showed little relationship with pain interference. However, the absence of close friends or absence of frequent contact with close friends was strongly associated with an increased risk of pain interference. After controlling for other covariates only a couple of associations remained significantly strong. They were, I) respondents who were widowed were significantly more likely to report pain interference with daily activities than their married counterparts, even after adjusting for age, ii) those with fewer living children or infrequent contact with them were less likely to report pain interference. These	Unclear The cross-sectional nature inflicts limitations on interpretations of the findings of this study. The sample drawn from a specific geographical region in England had a limited representation of the general adult population from ethnic minority groups particularly in older people, restraining the generalisability of the results to these groups.

		findings make sense and bear close resemblance to the evidence from prospective cohort studies of all-cause disability in older adults.	
3. Weismann *et al.*, 2014	Unclear The study's research question was to evaluate extent of pain outcome under the influence of exposure variables namely chronic morbidity and psychological resources (esteem, support) and sense of coherence.	Regression analyses results showed that morbidity and sense of coherence only predicted for pain outcomes in this population. In multinomial hierarchical regression, there were no significant associations between psychological resources (self-esteem, support etc.) and pain outcome.	No The sample consisted of multi-morbid respondents, over represented by women and a small sample size. Sample was selected from a GMP in a town in US, so results can not be generalised.
4. Leung *et al.*, 2015	Yes The study addressed a focussed issue of association of social networks and support on pain onset and progression in Singaporean community-dwelling older adults. This study used prospective	The results in binomial logistic regression models showed that living with more people had a strong negative association with the onset of chronic pain among women even after adjusting for confounders. There was a significant association	Yes It was a longitudinal study with a large sample size, which was nationally representative, and the results were generalisable to the older population in Singapore. The sample was stratified by gender and ethnicity.

	data from a nationally representative Social Isolation Health and Lifestyles Survey. Clearly defined outcome and exposure variables. It defined its chronic pain outcome as having lasting mild pain or more in the past one month. Lubben's revised social network scale was used to assess the social networks of the respondents outside the household. Other confounding variables were identified and controlled for in the analyses, when making associations.	between weak social networks outside of the household with the progression of chronic pain among women. A similar trend was observed in the onset of chronic pain. These findings are in agreement with the literature. For example, a longitudinal study on Swedish women where social support was identified as a protective factor against sustained pain. Many studies have also identified female gender as having a higher pain prevalence, which was reported in this study as well.	
5. Richardson *et al*., 2015	Yes This study explored the qualitative aspects and meaning of activity an involvement in older people's life and subsequent role on their chronic pain experience. Social activity, physical activity and involvement	The results showed that the key to living well with chronic pain was being active physically and socially, and being involved in life, while maintaining a flexible attitude and willingness to adapt activities.	Yes Even though it was a small sample size, the population from which the sample were chosen from for the interviews was nationally representative and included a large cohort sample of a longitudinal study.

	were exposure variables under investigation and social network was an important measure in maintaining physical activity as demonstrated in the themes of the interviews.		
6. Lee *et al.*, 2016	Yes This study investigated the effects of social support and cognitive functions on arthritis pain and depressive symptoms in a sample of older people. Both exposure and outcome was measured using subscales developed by the co-authors of the study.	The results showed that higher cognitive functions even with lower social support predicted lower levels of arthritis pain. Cognitive functioning has a significant negative linear effect on depressive symptoms and pain, but social support has a negative linear effect on pain only.	No Random selection of sample for the study, but small sample size because of strict selection criteria, then subsequent attrition of sample due to deaths and a higher percentage of Caucasian respondents (with higher than average education and income); all these restrict the generalisability of results.
7. Hung *et al.*, 2017	Yes This study aimed to evaluate relationships between family support, depression and pain outcome in arthritis patients aged 65 years and over. Both social support and pain	The results of logistic regression indicated that no single support separately from family (spouse, children, other member) was significantly associated with pain outcome.	Yes It was a cross sectional study obtaining nationally representative data from 2012 Heath and Retirement Study of US adult population. The sample used in the

	outcome were assessed using measures of self-report.	However, with rise in source of support, there was a trend towards lowered pain reporting. But when overall family support score was tested for associations with pain, there was no significant results depicted.	analyses were older people aged 65 and over. The sample had a wide range of demographics, health status, and family information.
8. Musich *et al.*, 2019	Yes This study aimed to find out the protective effects of high resilience and diverse social networks on pain severity and interference among older adults. Both social network and pain were assessed using measures that were validated and have been used in earlier studies.	The results of logistic regression showed that there were no significant associations between diverse social networks and pain outcomes. However negative attributes such as depression, stress, poor sleep depicted significant associations with both pain severity and interference outcomes in this sample population.	Unclear Participants were respondents of a cross-sectional survey conducted by insurance companies, which had a 29% response rates to their mailing list generating a stratified sample.
9. Mallon *et al.*, 2021	Yes This study aimed to evaluate the moderating effects of social support and depressive symptoms on pain in older people. Clearly defined measurements were	The results of the analyses showed some interesting findings, contradicting the study hypothesis. An increase in perceived social support influenced the relationship of depressive	No Generalisability of data is restricted as the sample had a strict inclusion criteria, missing the recruitment of GPs in rural areas of Germany. Also a very large dropout

	used fro both general perceived social support, and pain intensity and disability.	symptoms and pain intensity resulting in higher pain intensity scores.	(41.5%) as it was a longitudinal study, hence survivor bias caused the sample population and thus the results restrict its applicability and external validity.

The overall quality of the studies in this review was good, however, because of high to unclear attrition biases, the results of the overall review could not be generalised. This is because the studies had strict inclusion criteria. Furthermore, due to dropouts and loss to follow-up the sample was reduced further and potentially different to the target population.

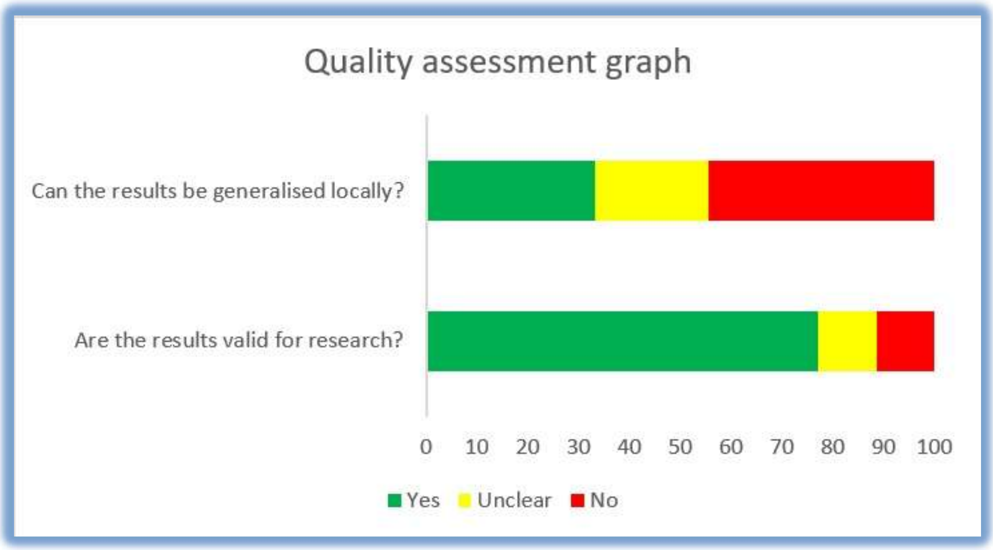

Figure 4. 3 Quality assessment graph: overall quality of the review presented as percentages across all included studies- Quality of the overall review of included studies demonstrated that the results of the current research were approximately 80% valid. Owing to only 30% generalizability of the current research, the results could not be applied to all locally.

4.4.7 Data synthesis

Summary of included studies

The total number of included studies in this review was nine, out of which only one was qualitative and eight were quantitative. Methodologically, the studies were either cross-sectional or longitudinal (see table 4.7), with sample sizes 226 (smallest sample in a longitudinal face-to-face interview) to 5215 (largest sample in a cross sectional survey) totalling 18106 across all studies. Five out of nine were cross-sectional and the rest were longitudinal; of which two studies were conducted in the UK, four in the US, another two in Germany and one study in Singapore. In addition, the quantitative studies can be categorised under two different groups of exposure variables. One group of social construct was a) the structural network outside the household that encouraged socialising, involvement, physical activity and engagement. The second group was of social construct b) the psychological pathway via which social networks operate well-being in older people; through perceived instrumental support, belongingness, appraisal, and self-esteem. Table 4.8 demonstrates the grouping of studies under the two exposure variables identified in this review. There was therefore a large amount of heterogeneity amongst the studies included making a more refined synthesis such as meta-analysis not feasible. Hence the studies of this review were qualitatively synthesised using a narrative and descriptive tables to group them where possible.

Narrative synthesis of result findings

Due to the methodological differences of the included studies (Table 4.7 demonstrates the grouping of studies based on study design, dropouts and external validity), there were limitations to how inferences could be made. For example, the findings of the cross-sectional design limit the inferences made to a correlational nature rather than causal; as they did not have follow-up data for ascertaining temporal ordering of causal relationships and many of the associations observed specifically in studies under this group.

Of the four longitudinal studies included, only two (Leung *et al*., 2015; Richardson *et al*., 2015) had good external validity and therefore high generalisabilty (refer to table 4.7). Secondly, the studies used valid reliable measurement tools indicating an increased credibility of findings for significant associations where found (Leung *et al.*, 2015; Lee *et al.*, 2016; Musich *et al.*, 2019). There were similarities in the studies background literature (where epidemiological studies on pain had similar cohort characteristics in terms of socio-demographics, role of comorbidities and depression on pain outcomes, larger social constructs influencing health outcomes etc.). Some studies had large and nationally representative sample sizes, hence making the findings generalisable in that country (Leung *et al.*, 2015).

Interestingly, the group of studies that focussed on the structural and involvement part of social variables outside of the household predicted lower pain outcomes better than the group of studies that focussed on the perceived support aspect of the exposure variable. Perceived social support from family and friends did not show significant associations with pain outcomes after accounting for confounders in multiple regression models (refer to summary statistics in table 4.4). Whereas, better structural networking, meeting with friends and involvement in activities outside of the household showed significant relationships with lowered pain interference and progression even in multiple regression models (refer to summary statistics in table 4.4). However, the depression variable attenuated the effects of exposure variable in most of these significant associations.

None of these result findings should be accepted without accounting for the potential biases involved, especially measurement and classification biases (refer to table 4.5). These limitations need to be stated and implied when interpreting results for conclusions. Not all of the included studies used the same assessment tools for defining and measuring exposure variables. This affects the validity of results and comparability of various study findings. The outcome variables across these studies was assessed either by a pain related question (self-reported, when asked most common question about presence and intensity of pain) or a validated pain assessment tool. Table 4.9 demonstrates the grouping of studies based on the two basic outcome measures identified in this review. Self-reported measures of pain used by most of the included studies was a potential limitation that could have caused information bias (due to misclassification), in-turn leading to either over-reported or under reported pain experience. The other set of studies however, used a validated tool to assess pain experience of its population. Therefore, when interpreting result findings about associations with pain outcomes, it needs to be acknowledged that under-reporting would have caused shielding of many significant relationships with predictor variables, leading to systematic bias (measurement bias in this case). However, it is noteworthy that all the studies using a validated tool for its pain outcome measure explored the predictive influence of social support on pain with the only exception of Musich *et al*. (2019), in contrast to that studies that explored the role of socialising, interacting with friends and family, and engaging in community activities on pain outcomes which used self-reported pain questions. Moreover, even though two studies in the review used validated or reliable tools to measure both social support and pain, the association was confirmed as non-significant between the two. Unfortunately, none of the studies used standardised validated tools for both social network/activity and pain outcome together when finding associations; a limitation that needs to be acknowledged. While we mention limitations, it is important to state that the attrition bias was high or unclear in more than half of these studies (refer to table 4.5), with not much information on the non-responders. Attrition is a major methodological problem in studies and can deteriorate generalisability of findings if those who stay in the sample differ from those who dropout. In studies that included follow-up periods such as longitudinal study by Mallon *et al*. (2021), the dropouts due to comorbidities and deaths caused survivor bias and could have affected result findings of that study. However, the drop-outs due to high mortality also point towards a typical characteristic of the older population with comorbidities as was the case in Lee *et al*. (2016) study, hence, would not have necessarily disturbed representativeness, or negatively affected external validity (generalisability). But even though these dropouts co-exist in research studies among older age adults with disease outcomes, it needs to be acknowledged that they affect the study results and hence some bias is unavoidable.

Moving on to the exposures explored in the included studies, four papers focussed on social networks as the exposure variable in this review. From the nine included studies, a trend was noticed in more than half of them, which was the exploration of the social support variable for the prediction of pain outcome. A uniqueness of these six papers common to all was its sample population suffering from pain and multi-morbidity (such as depression, and arthritis). These studies measured the social support variable using different measurement scales but what they had in common was a classification of social support into emotional, tangible/instrumental, appraisal and belonging support. Interestingly, studies that measured the role of the support variable did not conclude any significant associations with pain outcome after controlling for the covariates (socio-demographic, function, and health). A possible explanation to this might be because in older age, your spouses or partners (mostly around similar age as you) need support themselves, or die leaving the support role for adult children. However, parents may not actively seek support from children due to set expectations (historically older people have seen their role with children as a ‘parenting’ one), and a desire not to burden their already busy adult children. Moreover, the role of support from separate family members on pain outcome demonstrated lowered pain outcomes with spousal support than with children support in some of the studies (Hung *et al.*, 2017). Interestingly, another study by Mallon *et al.* (2021) demonstrated a negative role of social support on pain outcome. The authors provided an explanation stating that the community living sample population was particularly suffering from multiple comorbidities (eligibility requirement for the study research question), hence their levels of support requirements was higher than usual. Moreover, this sample of older people were mostly married and living with their partners (demonstrated in the results of the cohort characteristics), therefore positioning this sample under the pressure of providing support for their older partners.

The other studies focussed on the role of the social network structure variable that includes number of and visits (phone calls, meetings) with family, friends, neighbours, relatives; and influence of social engagement and activities with friends, religious or leisure organisations, and its effects on pain outcomes. The trend revealed that the exposure variable social network/activities in these studies played a benefitting role on pain interference more than on pain intensity. The qualitative study that explored social activity as the exposure variable concluded that being physically active and socially involved helped to age well and live well with pain. It can be argued that social networks play a protective role against pain in these older people through psychological pathways (conceptualised in Berkman’s model) of social engagement and involvement. Social engagement in activities keeps one physically active, and functioning and hence lowers pain interference with daily activities as was demonstrated in this review (Peat *et al.*, 2004; Richardson *et al.*, 2015). Social engagement with friends and community (Peat *et al.*, 2004); Richardson *et al.*, 2015), and networking outside the family household (Leung *et al.*, 2015; Richardson *et al.*, 2015) were shown to influence and keep the older people active both physically (involvement) and mentally (through socialising). The qualitative study in this review also made conclusions along similar lines where involvement in day to day activities enhanced healthy ageing among the pain free sample plus those who had severe pain but it did not stop them from ADL and IADL (Richardson *et al.*, 2015).

Although the social support variable is also one of the pathways through which social networks operate their roles on health outcomes and pain outcome in particular, it did not exactly fit into the definition of structural social network (visual and non-visual) in the current dataset, which aimed to explore the physical and structural aspect of an older persons social construct regulating pain outcome. It also did not encompass the definition for social engagements/activities which was another exposure variable for the current dataset being used to predict pain outcome. According to Berkman *et al.* (2000), social networks use the more proximal (closer to an individual) pathways such as social influence, social support and social engagement to control the health outcomes of an individual. Therefore, for the wider scope of this study, and in order to gather, explore and critique evidence the physical (non-visual, visual social network) as well as psychological (social support and engagement variable) aspects of social network predicting the outcome of pain in older people were included. Hence these studies focussing on perceived social support were included. Therefore, this literature review apart from finding a clear rationale for the empirical research of this thesis, and exploring what little is known about the research question to bridge the gaps, also gathered, explored, critiqued and synthesised the wider evidence in literature around the psycho-social aspect of an individual's network predicting chronic pain outcome.

The majority of the studies used quantitative methodology and statistical data analyses to test their hypothesis. Therefore it was imperative that they used survey questionnaires and had larger populations and quantifiable data that could be generalised, and hence produced more reliable result findings with better external validity. This was the case with the cross-sectional studies such as Peat *et al.* (2004) and Hung *et al.* (2017) and the longitudinal study by Leung *et al.* (2015). However, because some of the studies with follow-up period had high risk of attrition bias, the sample population did not necessarily represent the target population, therefore reducing the external validity of those studies (Lee *et al*., 2016; Musich *et al*., 2019; Mallon *et al*., 2021).

The included studies were conducted over the period of three decades, however approx. 80% of the studies included in this review had been conducted in last eight years. This indicates that although the role of social networks as health (in particularly the outcome of chronic pain) promoting factor had been appreciated more than three decades ago, not much empirical research exploring the influence of social networks on pain outcomes was done until the last decade. The earliest study by Weinberger *et al*. (1990) investigated the role of psychological aspects of social constructs (support from family) followed by the Peat *et al*. (2004) study that analysed the roles of social networks (visual and non visual) on pain interference with daily activities. Then after a period of ten years, the rest of the seven studies were conducted that explored the roles of social network, activity, and support on pain outcomes, some of them depicting/concluding a protective role of these predictor variables on the experience of pain in older people.

Through this review it was identified that even though there are limitations in the literature on this topic such as, self-reported measures used for outcome variable, no standard measures for classification and assessment of exposure variables followed, the use of cross-sectional study design, and consequently no causation found, a narrow selection criteria of sample population, mostly non-generalisable results because of narrow sample characteristics (either very healthy or morbid/diseased) and in some cases a small sample size, an under-representation of minorities; they all still point towards a positive influence of social variables on pain outcomes in unadjusted models and also some in adjusted models in older people. This was more common in women such as the Leung *et al.* (2015) finding where social networks outside the household for women showed protective effects on pain progression; and finding by Peat *et al*. (2004) where the absence of ties with close relatives was associated with greater pain interference for women only. However, the study by Peat *et al*. (2004) also made a contrasting conclusion for its male respondents that a greater number of children and frequent contact with them was associated with increased pain interference. They discussed this critically in their paper pointing at the high demands of children from fathers. They stated a possible explanation, that the rating of pain interference with daily activities reflects actual or perceived demands and expectations from children, particularly on fathers; although, understanding this association clearly requires more detailed, prospective and longitudinal investigation.

Even though the absence of social ties and contact with close friends were most strongly associated with pain interference in the Peat *et al.* (2004) study, it was weakened after adjusting for socio-demographic variables and became non-significant after adjusting for depression. This was another trend noticed in the studies where depressive symptoms caused the association between social network/support on pain outcome to be either attenuated or non-significant. The study by Musich *et al.* (2019) demonstrated that high resilience, medium, and diverse social networks reduced the likelihood of moderate and severe pain severity. However the characteristics most strongly associated with moderate and severe pain severity and interference were depression and stress. Another study by Mallon *et al.* (2021) found that increased perceived social support amplified the association of depressive symptoms on pain intensity; this was the opposite of what earlier studies on the same subject had demonstrated. It concluded the negative impact of depression on pain in older adults, which was in line with other studies in the literature; but the stress-buffering effect of perceived social support could not be shown in the analyses on this dataset. This could be due to the distinct characteristic of the multi-morbid cohort. Despite the high age in the cohort, the larger amounts of participants were still married and shared a household with another person. This must have made support (especially instrumental) accessible for those in pain, suffering from morbidity and needing increased social care needs. The evidence in background literature also supports and justifies this finding where instrumental support in particular has shown to negatively impact pain behaviours (where you totally prevent and discontinue pain related activities); whereas emotional support that helps with self-efficacy and esteem reduces pain behaviours and you make living with pain easier by adjusting with activities and not totally discontinuing or preventing them. This could further influence pain interference in daily living and pain related disability over the years. The study by Richardson *et al.* (2015) made some very good conclusions along these lines where both older adults without pain and with pain but no interference in daily activities, produced similar narratives. The overall results of the qualitative interviews from both these groups of older adults established that living well with pain was an outcome of adjusting activities and attitude about pain, keeping oneself both physically active and socially involved, building esteem and self-worth.

The quality of studies and assessment of risk of bias for the included papers was described in the presented tables and graphically represented for ease of understanding. The review depicted that some studies (Leung *et al.*, 2015; Richardson *et al.*, 2015; Hung *et al.*, 2017) had good external validity and hence locally generalisable findings but there was a trend across most of the studies showing an overall low risk of bias (such as Peat *et al.*, 2004; Leung *et al.*, 2015; Richardson *et al.*, 2015; Hung *et al.*, 2017; Musich *et al.*, 2019).

It is evident from this review that chronic pain problems and its associations with measures of social network need to be explored in more depth, with an emphasis on using standardised assessment criteria for exposure variables, more commonly including structural aspects of social networks, social integration (belongingness, involvement) along with support measures and exploring wider sample population characteristics. Psychometric measures of pain, and standard valid assessment tools need to be explored rather than stand alone self-reported measures assessing body pain etc. These are some gaps the current study aims to bridge by using psychometric measures for pain severity and pain interference outcomes and assessing these outcomes using well-established, validated tools such as the multidimensional Brief Pain Inventory (BPI) scale (Cleeland, 1989; Leveille *et al.*, 2008; Eggermont *et al.*, 2014), for severity as well as for interference with daily activities.

Table 4. 6 Grouping the included studies based on study design

a) Cross-sectional (correlational rather than causal)	b) Longitudinal (drop-outs, generalisability)
Weinberger *et al.*, 1990	Leung *et al.*, 2015 (low, high)
Peat *et al.*, 2004	Richardson *et al.*, 2015 (low, high)
Weismann *et al.*, 2014	Lee *et al.*, 2016 (high, low)
Hung *et al.*, 2017	Mallon *et al.*, 2021 (high, low)
Musich *et al.*, 2019	

Table 4. 7 Grouping the included studies based on definition of exposure variable

a) Structural social variable (social networks, involvement, activity, engagement outside household	b) Psychological social variable (perceived social support, instrumental, appraisal, belonging, esteem)
Peat *et al*., 2004	Weinberger *et al*., 1990 (validated tool)
Leung *et al*., 2015 (validated tool)	Weismann *et al*., 2014
Richardson *et al*., 2015	Lee *et al*., 2016 (reliable tool)
Musich *et al*., 2019	Hung *et al*., 2017 (reliable tool)
	Mallon *et al*., 2021

Table 4. 8 Grouping the included studies based on assessment of outcome variable

a) Self-reported measure using a question on pain experience	b) Validated tool to assess pain
Peat *et al*., 2004	Weinberger *et al*., 1990
Weismann *et al*., 2014	Lee *et al*., 2016
Leung *et al*., 2015	Musich *et al*., 2019
Richardson *et al*., 2015	Mallon *et al*., 2021
Hung *et al*., 2017	

4.6 Conclusion

This systematic search identified nine papers that explored and identified the protective roles of social networks, social support, and social engagements. Overall the studies revealed that older adults were at higher risk of chronic pain outcomes, additional comorbidities and their consequences. The studies mostly concluded that both structural and psycho-social aspects of older people influenced pain outcomes positively when analysed on its own, however the effects were not significant when covariates such as comorbidity factors, depression, and functional status were included. This brings to a conclusion that even though social networks can benefit the pain experience in this population but factors such as depression, disability and other age-related diseases take charge and influence healthy ageing. However, background literature provides evidence that even these other health factors are related and strongly associated with both social networks and pain in older ages. Therefore it is a complex mechanism that operates function and health outcomes as we age. But nevertheless, having strong structural social networks with support (mostly emotional, esteem and belonging) and involved in social activities to be physically active helps better to overcome the chronic health outcomes such as pain.

Interestingly were the findings from two studies, one which demonstrated that an increased number of children (a measure of social network) was associated with an increased pain interference in men (Peat *et al*., 2004); and the other which showed higher levels of support were related to increased depressive symptoms and pain outcomes (Mallon *et al*., 2021). However, the study by Peat *et al.* (2004) was cross-sectional and could not confirm causation. They also had low generalisability and external validity of findings. The study by Mallon *et al.* (2021) acknowledged their sample population followed strict eligibility criteria with comorbidities present, and also had a high dropout rate during follow-up; therefore findings were not necessarily generalisable. Therefore, there is a need for studies in future to generalise these findings and make concrete conclusions.

Nevertheless, the positive role of both structural and psychological aspects of social constructs of older people (that included structural social network, social activities, social support) was identified in many studies that could guide policy interventions. These interventions include psychosocial counselling of older people and their close ones (friends, relatives, partners) to provide support in managing pain, and programmes to increase community activities and engagement to help alleviate chronic pain interference in day-to-day living, and increase a sense of coherence, and self-esteem.

Following on from the studies included in this review, this study's secondary data analysis aims to explore the association between social networks/activity and pain outcomes solely among post-retirement older adults living in the community in older adults aged 70 years an dover. This should potentially minimise the risk of exploring the work-related pain outcomes and confounding measures of non-occupational chronic pain in older people. Restricting the study sample to non-working older people only will also makes sure that the social network component in the analysis is purely from social ties (children, friends, relatives), and social engagements related to religious or leisure activities, (e.g., churches, social clubs, societal activities of daily living etc. giving a feeling of self-worth and self-satisfaction, involvement in community etc.). Work related social activity is not within the scope of the current research, given the more formal nature of the relationships. This is also the basis for investigating older adults living independently in the community, and not nursing home residents, so that social networks are characterised by relationships with family and friends, and social activity includes engagements in their community.

Most of the excluded studies in this review did not fit the inclusion criteria owing to reasons such as belonging to middle ages and working populations, belonging to nursing homes, senior centres or day care organisations, receiving formal social support, or because social networks were explored in relation to other chronic outcomes other than pain such as cognitive impairment, depression, and quality of life.

Social networks involve cascading factors that play a complex role in the lives of older people, including upstream macro (socio-economic factors), mezzo (social network structure and function) and downstream micro (engagement in social activities) pathways to influence health outcomes, as previously outlined. Social networks, social activities, and social support influence chronic pain among the older adult population. The current study focussed on older adults, their social networks and social activity, and both pain severity and interference outcomes, at baseline as well as at 18-month follow-up. Exploring pain outcomes related to intensity or severity along with including interference in daily activities is always an advantage and gives a more complete picture of an older persons pain experience. Moreover, pain outcomes are usually manifested with interference with everyday living before resulting in disabling pain, and subsequent disability in severe cases if not treated. This increases incrementally with age particularly in post-retirement older adults.

Overall, this review has provided legitimacy to and confidence in Berkman's conceptual model of social networks and health (described in chapter three, section 3.3), where distal (further to an individual) factors play a role in shaping the more proximal (closer to an individual) factors when predicting health outcomes. It has been argued in literature and now reinforced by the findings of this review that social support on its own was not the only critical pathway that influences better health (such as lowered pain experience) in older people, but the cascade of causal processes from macro social environment to mezzo and micro social environment that affects health outcome. These macro social variables involve the demographic and socioeconomic factors, mezzo variables are structural networks (size in terms of family, friends, relatives and frequency of visits) and the micro variables are support and engagement in activities.

Ageing often involves decreased physical and social abilities, which bear a great toll on individuals and their families, challenging the sustainability of health and social systems (World Health Organization, 2015). Therefore, it is inevitable to not only study factors that influence ageing but also explore the factors associated with ageing such as chronic pain; and the reasons for differences amongst ageing populations; the varied consequences of ageing around the world, in different cultures, countries etc.

5. METHODOLOGY

5.1 Introduction

This chapter introduces the study's methodological approach, the associated types of study designs used in epidemiological research, important concepts in epidemiology and the secondary data analysis approach. It further outlines the rationale for using secondary data from a cohort study such as the Mobilze Boston Study including its strengths and limitations.

5.2 Epidemiological study design

Study designs have profound effects on the interpretation of study results; therefore the decision to employ a specific design to conduct a research study should be considered carefully. An appropriate study design is a vital component aiding the validity of results and reducing bias (Valentgas *et al*., 2013). To comprehend the various different study designs in epidemiological research, it is important to first understand the basic concepts and definition within epidemiology.

Epidemiology is often described as the basic science of public health. It is a quantitative discipline that relies on basic knowledge of probabilities, statistics and sound research methods. It is also a science of causal reasoning based on developing and testing hypotheses grounded in scientific fields such as behavioural science, biology, physics and others (Centres for Disease Control and Prevention, 2012). Epidemiology has evolved over several decades, since its origin over a century ago, and has remained a relevant tool in understanding the emergence of new diseases and health events (Frerot *et al*., 2018). Epidemiology tries to explore how often health-related events occur in different groups of people, and why these different groups vary in patterns of health and diseases. It then uses this information to control and prevent health problems. Although the pioneers of epidemiology were more concerned with infections and the aetiology of chronic diseases, more recently epidemiological studies have focussed on evaluating interventions, and assessing the provision and impact of health services (Martin, 2013).

There have been many researchers who have defined epidemiology over the past few decades. Frerot *et al.* (2018) in their paper on changing definitions of epidemiology described the works of Lilienfeld (1978) on providing an understandable definition for epidemiology suitable for all types of diseases and populations. According to Lilienfeld (1978) as stated in Frerot *et al*. (2018), epidemiology is a method of reasoning about disease that deals with biological inference derived from observations of disease phenomena in population groups. Further to this, Evans (1979) analysed the works by Lilienfeld and proposed a different definition stating that epidemiology is the quantitative analysis of the circumstances under which disease processes, including trauma, occur in population groups, factors affecting their incidence, distribution, and the host response and use of this knowledge in prevention and control. Since the work of Lilienfeld and Evans, new definitions of epidemiology have been proposed. In another definition, epidemiology is described as the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems (Last, 2001).

The main focus of this study is the epidemiology of pain occurrence in older people and to ascertain the role of social network factors on their pain outcomes. An epidemiological study involves describing and understanding patterns of disease occurrence, distribution and risk factors in human populations (Weiss & Koepsell, 2014). The participants studied in this type of research are individuals from specified social groups, people recruited through primary research, or data on people recruited through previous studies. Information on these participants can be gathered by methods such as observation, questionnaires, interviews, physical examinations or physiological measurements. Secondary data is obtained from appropriate and available studies along with relevant guidebooks and codebooks.

5.2.1 Classifying epidemiological studies

Descriptive & Analytical studies

Epidemiological studies can be classified based on different parameters. Based on the type of analyses conducted, the epidemiological study falls into two basic types: descriptive and analytical. Descriptive studies include disease occurrence, description, and frequency (e.g. prevalence and incidence rates). Alternatively, analytical studies focus on identifying risk factors, aetiology, or even protective factors of a disease outcome. Thus, descriptive studies are mainly conducted for a new disease, to characterise, quantify and determine its frequency in relation to demographic characteristics, place and time. The distinguishing characteristic of such a study is that it is undertaken without any specific hypothesis about the causes or patterns of association. On the other hand, analytical studies are undertaken to test one or more hypotheses; for instance, whether or not a certain exposure influences the risk of having a disease. Analytical studies are typically undertaken to test any hypothesis concerning whether a certain exposure to risk or protective factor causes a certain outcome (Weiss & Koepsell, 2014). Given that the current research adopts an analytical approach, concepts of exposure and outcomes of interest are detailed in later sections of this chapter.

Incidence and Prevalence studies

According to Pearce (2012), epidemiological studies are broadly described according to two characteristics, a particular population or a particular period of time (risk period). Within these characteristics, the two important types are studies of disease incidence and studies of disease prevalence. Such studies are descriptive in nature and explore disease occurrence and their frequency (Weiss & Koepsell, 2014). Descriptive studies have been used by public health specialists, health care providers and health promoting agencies in making decisions on the allocation of resources, surveillance of diseases, and planning of the health prevention and promotion programmes (Grimes and Schulz, 2002).

Incidence studies measure exposures, covariates and time taken to develop the disease outcome of all population members. When studying disease etiology incidence studies are usually the preferred approach. However, they involve many resources and lengthy periods of follow-up (Pearce, 2004). Hence, in practice it is often proposed to study the ‘prevalence’ of disease at a particular point in time. However, this approach has a major limitation with assessing causation (i.e. whether an exposure increases disease incidence). This is due to differences in disease prevalence between two groups owing to differences in age-specific disease incidence, disease duration or other population parameters (Rothman *et al.*, 2008). Nevertheless, prevalence studies may be of interest in itself, as it measures the population burden of diseases at a given point in time. For instance the current study aims to study the prevalence of pain on older adults with both cross-sectional and longitudinal data; and effects of exposure variables such as social network/activity on outcome of pain. Therefore, it would be categorised under prevalence study.

Experimental & Observational studies

Epidemiological studies can be broadly distinguished between experimental and/or interventional studies and observational studies. When a researcher modifies any given variable related to the study participant that alters the development or course of an outcome, it falls under the classification of an experimental or interventional study (Faraoni and Schaefer, 2016). However, there arises many situations in healthcare services where experimentation is unethical, difficult to implement, inappropriate to generalise (for example, to experimentally study the effect of cigarettes on lung cancer). One alternative to experimental design is the use of observational methods to test hypotheses (Black, 1996; Lu, 2009), evaluate exposures (Concato *et al*., 2000; Lu, 2009), and analyse or evaluate complex systems (Rychetnik *et al*., 2002; Anglemyer *et al*., 2014). Therefore, in an observational study, the researcher collects data on factors (such as exposure/predictor) associated with the occurrence or progression of the outcome without any attempt to alter the exposure status of the participant (Faraoni and Schaefer, 2016).

Another way to classify epidemiological study designs according to Munnangi and Boktor (2020) is based on whether an exposure and an outcome are related to each other either by association or causation (both of these concepts are detailed in later sections of this chapter). Furthermore, based on the relationship between exposure and outcome factors, Chatburn (2017) classifies epidemiological studies as experimental or non-experimental/observational. In an experimental design, participants are assigned either an intervention or a control (comparison) group to isolate the effects of the intervention. Researchers try to identify causal links between interventions and an outcome of interest by being able to control various aspects of the experimental study design. However, on many occasions this may not be feasible or suitable; which is why observational studies are conducted. Observational studies are conducted in a non-controlled environment without interfering or manipulating with any aspect of the study and therefore are non-experimental (Chatburn, 2017).

Observational studies have been criticised as having less validity when compared to Randomised controlled trials (RCTs) owing to their results being more vulnerable to chance, bias or even confounding variables (MacMahon and Collins, 2001, Badu *et al.*, 2019). RCTs provide evidence of the highest certainty if certain criteria, (e.g., randomly assigning participants to conditions, blinding the investigator to group membership, etc.), are met with precision (Faraoni and Schaefer, 2016). RCTs are therefore seen as the gold standard for evaluating the safety and efficacy of an intervention, primarily due to randomisation of group allocation ensuring that the participant groups only differ on that variable(s) being manipulated (Lu, 2009). This method increases the validity of study results by minimising biases and confounding (concepts discussed in later sections). However, like all research designs there are limitations to RCTs. For example, RCTs can involve intensive resources, can focus on a small population sample, and can focus on more short-term effects of an intervention (Lu, 2009). An RCT can prioritise the validity of results at the expense of generalisability (Boyko, 2013), and thus may not be able to answer some questions of clinical importance.

As an alternative to the true experimental design, observational studies can also generate credible evidence of intervention effects, and may be more clinically relevant than RCTs, and produce results with higher generalisability (Boyko, 2013). Furthermore, they can be more suitable to detect rare or latent effects of interventions (Black, 1996), and there is an expanding body of literature using observational designs owing to them being less resource intensive (Black, 1996). This is particularly relevant to secondary analysis through increased availability of already collected electronic healthcare data over the last few decades (Boyko, 2013).

Observational studies can play a significant role in healthcare, including the study of the use and effects of medicines in large populations (Schneeweiss *et al.*, 1997) and pharmacoepidemiological research (Boyko, 2013), as well as being useful in situations where RCTs may not be viable for ethical reasons (Black, 1996; Boyko, 2013). Observational study design may also make important potential contributions in conjunction with RCTs. For instance, an additional observational study could be run in situations where long-term adverse events needed to be monitored or observed that did not appear during the time interval over which the RCT was conducted, or in situations where it is required to assess whether the trial findings apply to a different populations excluded from the RCTs due age or gender specifications, presence of comorbid conditions (vulnerable populations), or other factors (Boyko, 2013).

5.2.2 Types of observational studies

Observational studies have further been divided into descriptive and analytical studies, which is described at the start of this section (Parab and Bhalerao, 2010). Experimental or interventional studies on the other hand are further described under randomised control trials, non-randomised controlled trials, and quasi-experimental designs (Thiese, 2014). The randomised trial is a comparative study where participants are randomly assigned to one of two groups. This research examines a comparison between a group receiving treatment and a control group receiving treatment as usual, an alternative, or receiving a placebo. Herein, the exposure to the intervention is determined by random allocation (Guerrera *et al.*, 2017; Bhide *et al.,* 2018).

The term observational study describes a wide range of study designs including prospective and retrospective cohort studies, case-control studies, and cross-sectional studies, a defining feature of which is that any intervention studied is determined by clinical practice and not the research protocol (Parab and Bhalerao, 2010). For example, data from large, prospective observational studies provides useful information about the safety and efficacy of medicines (intervention) in daily clinical use. However, observational trials have inherent limitations in terms of their susceptibility to bias and confounding, as well as restricting their ability to define causality. On the contrary, their strengths are that they reflect daily clinical practice more closely than randomised controlled trials (RCTs), both in terms of the heterogeneous patient populations that are included, and the medical interventions that they receive. Therefore, observational trials can provide clinically relevant information that is not necessarily provided by RCTs (Yang *et al.*, 2010). Below are the different types of observational study designs explained in more detail with their associated weaknesses and strengths.

5.2.3 Cohort study design

A cohort is a group of people who share a trait or a particular characteristic and are followed over a period of time to determine incidence of mortality from a specific disease, or other outcome (Morabia, 2004). Cohort studies are sometimes known as follow-up studies as they follow and compare the subsequent occurrence of any illness or disease outcome among a group of people whose exposures differ naturally and not as a result of random assignment (Weiss & Koepsell, 2014). Since cohort studies have a follow up period, they are further classified into two categories: prospective and retrospective cohort studies (Song & Chung, 2010). Simpler in design is a prospective study; this is when a cohort is followed forward in time. A retrospective study design means the disease outcome is already established in the study population, and the outcome is assessed retrospectively. Terms prospective and retrospective indicate the time when a cohort of participants is identified for the study relative to the study initiation (Boyko, 2013; Weiss & Koepsell, 2014). The figure 5.1 briefly describes both these study designs.

A cohort study design has a number of applications such as investigating causal relationships (potential causations), estimating incidence and examining prognosis (Goldacre, 2001; Rochon *et al.*, 2005). Cohort studies measure exposure and outcome in temporal sequence thereby avoiding the debate as to which comes first, thus this design can demonstrate causal relationships (Lu, 2009). Its strength also lies in examining multiple outcomes from a single exposure and less chance of measurement error (Boyko, 2013). The weakness of a cohort design is its inefficiency in studying the incidence of a rare outcome, as patients are required to be followed-up for many years at a substantial cost. Selection bias (systematic differences in study groups in factors related to outcome) and bias due to differential loss (because of drop-outs, deaths, migration) adds to challenges in this study design (Lu, 2009). Additional limitations include the requirement of large sample sizes and longer periods of follow-up (Boyko, 2013).

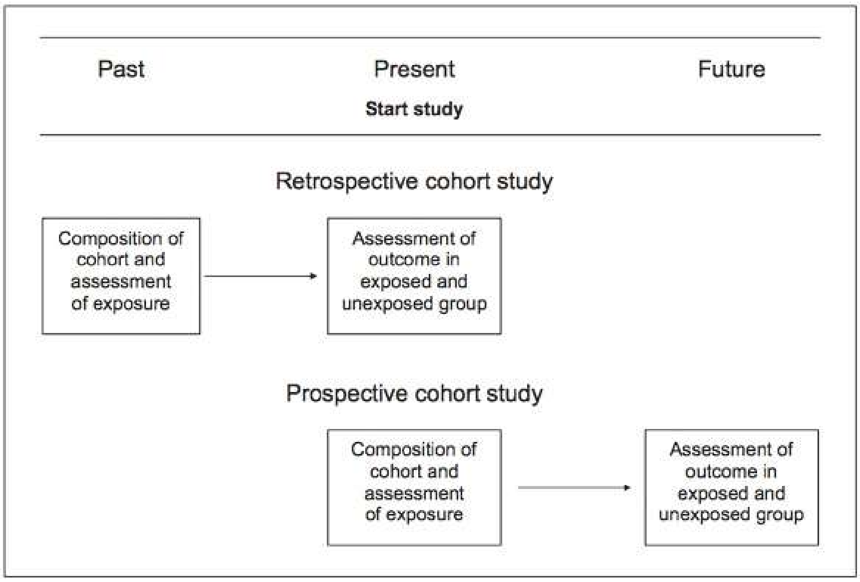

*Figure 5. 1 Cohort study design- Graphical representation of the timeline in a retrospective and prospective cohort study design (*Taken from Euser *et al.,* 2009)- Types of cohort study design based on timeline. First the retrospective study that assesses outcome in both exposed and unexposed groups in the present; and follows it back in time to investigate the cohort composition and type of exposures. Second the prospective study that investigates the composition of cohort and types of exposure at present and follows it forward in time to assess the outcome in both exposed and unexposed groups.

Prospective studies: in these studies, the researcher identifies the study population and its exposure (risk/protective factors), at the start of the study. The characteristics (demographics and covariates) of the study population are identified and then split between cases and non-cases at baseline. Those participants in the population with the disease outcome already present are cases and those without are non-cases. To make true associations and have unbiased results, only the non-cases are followed up over time to explore associations between the exposure factors and outcomes. The cases with the disease outcome already are intentionally not followed-up because if they had the disease progression over time, it would be difficult to associate it with the exposures at baseline because they already had the disease at baseline, so the association expressed would have bias. Such studies are longitudinal studies, as they use population data both at baseline and then at follow up to generate results of associations and conclusions. They help in establishing temporal relationships between an exposure and the disease outcome (Pearce, 2012). Because data collection methods are part of the prospective design, it has the advantage of being tailored to collect specific exposure data and therefore may be more complete. The limitation of a prospective cohort study may be the long follow-up period (that is resource intensive) while waiting for events or diseases to occur (Song & Chung, 2010).

Retrospective studies: these studies assess those who have had the exposure to disease in the past and define current cases (with the disease exposure) and non-cases (without the disease exposure). These studies consider those who have the disease of interest to determine associations between the exposure and outcome. Retrospective cohort studies, also known as historical cohort studies, are carried out at the present time and look to the past to examine medical events or outcomes (Song & Chung, 2010). For a retrospective design, it is necessary to have sound data on exposure statuses of cases and non-cases since they depend on data that has been collected in the past; and therefore, there can be issues with regards to the relevance of the data (Pearce, 2012). The investigator has less control over data collection as a consequence. The existing data may be incomplete, inaccurate, or inconsistently measured between subjects. However, because of the immediate availability of the data, this study design is comparatively less costly and shorter than prospective cohort studies (Song & Chung, 2010).

5.2.4 Case control study design

The case-control design examines the relationship between any exposure factor with a disease outcome by comparing those with and without the disease (Mann, 2003). It is one of the most important designs for investigating causal hypotheses and potential causal-relationships (Boyko, 2013). This study design is usually retrospective in nature and aims to identify predictors of a particular health outcome. It is relevant when investigating a rare or chronic disease that results from long-term exposure to particular risk factors (Yang *et al*., 2010). This is in contrast to cohort studies, where they can be both prospective and retrospective (Boyko, 2013). Where on the one hand, cohort studies begin with the identification of the exposure status; the case-control study begins with the identification of the outcome (Boyko, 2013). In this particular study design, cases with a certain condition (e.g. hospitalised diabetic patients) are compared with controls (e.g. non-hospitalised diabetic patients); hence data collection is usually retrospective. The researcher goes through the patient's records (both cases and controls) to identify whether the development of the condition in one group was due to the presence of some causative exposure factor (Parab and Bhalerao, 2010).

Some of the strengths of this study design are its small population size and ability to examine a number of exposures, however, this is at the cost of investigating only one outcome at a time (Boyko, 2013). They are therefore more cost-efficient (Lu, 2009) than cohort studies (i.e. a smaller sample size is sufficient to generate adequate information because of a higher percentage of cases per study). However, its weakness lies in its ability to only examine a single disease outcome at a time (Boyko, 2013) and a greater potential for bias when measuring exposure. Both selection and recall bias are prone to occur because people with the outcome are more likely to remember certain antecedents, or exaggerate/minimise what they consider to be risk factors in case control design (Lu, 2009).

5.2.5 Cross-sectional study design

The cross-sectional study design sometimes referred to as a prevalence study measures the occurrence of a disease at one point in time. Such study designs establish both its exposure and outcome at the same point in time. Therefore, it can only provide information on disease prevalence (Lu, 2009; Pearce, 2012). Prevalence studies are vital to clinicians and healthcare providers since they influence the chance of a particular diagnosis and the predictive value of an investigation. This method is also used to examine the association between an exposure and an outcome (Lu, 2009). Where longitudinal studies such as the cohort study design uses population exposure data both at baseline and follow-up collection points to generate results of association with a disease outcome, cross-sectional studies uses population exposure data at a given point in time and disease frequency data at the same point in time to analyse associations between exposure and disease outcome (Lu, 2009; Pearce, 2012). However, to achieve temporality in associations made through cross sectional studies, longitudinal studies need to be conducted for confirmation on the direction of causality. A common limitation of cross-sectional studies is its imprecision on the direction of causality (Pearce, 2012).

This research approach is relatively quick and easy (Lu, 2009) because it does not require repeated observations over a follow-up period of time (Pearce, 2012), however, it does not allow cause and effect to be established, but instead measures the cause and effect at the same time without identifying on which variable is the cause and which one is the effect (Badu *et al*., 2019). In addition, it does not give information on the relationship between the two variables. The cross-sectional study has limited value in assessing a potential causal relationship since it may not be possible to determine whether the potential exposure preceded the outcome, except in very rare cases such as the eye color, ABO blood group where the exposure does not differ throughout ones life (Boyko, 2013). However, it is still the most common study design used in general practice research as these are inexpensive and can be carried out in a short time frame (Parab and Bhalerao, 2010).

5.3 Important concepts in epidemiological study design

Exposure, outcome and confounders

Both experimental and observational studies in epidemiology, when formulating hypotheses and research questions of interest must include one or more outcome factors, such as biological, physiological, symptom, function, general health functioning or even overall quality of life factors (Wilson and Cleary, 1995). The *outcome* of a study is a broad term for any defined disease, state of health or health-related event. There may also be multiple outcomes in some studies. Exposure is a term used in epidemiological studies that broadly applies to any factor that may be associated with the outcome of interest (Lee and Pickard, 2013). The term exposure is usually applied to the primary explanatory variable of interest, which is assumed or hypothesised to have an association with the outcome variable. The *exposure* of interest may be associated with an increased or decreased occurrence of any given health outcome and may relate to the environment (e.g., air pollution), or lifestyle (e.g., smoking habits, diet, exercise), disease pathology or genetically related. This exposure of interest may be termed a predictor, risk, or protective factor in different epidemiological studies when formulating research questions. The biological mechanism of action whether known or hypothesised guides the definition of exposure variables (Lee and Pickard, 2013).

The exposures and outcomes of interest are specific to the study hypotheses and should always be clearly defined before the study starts. Conceptualising a theoretical and biological link between the exposure and the outcome is preferable and helpful in defining both exposure and outcome measures in an epidemiological study (Lee and

Pickard, 2013). The exposure of interest in one study may be the outcome in another. For example, smoking is the exposure variable in a study examining whether smokers are more prone to developing lung cancer than non smokers; whereas it is as outcome of interest when evaluating the effectiveness of an anti-smoking intervention programme in reducing frequency of smoking in a specified population. More often than not the relationship between exposure and outcome variable may be noisy due to the presence of other factors that also have a relationship with the outcome of interest and are correlated with the exposure variable. This variable can either be termed as a confounder variable or as a covariate, and can lead to bias and confounding.

Bias and Confounding:

The results of any epidemiological study may either reflect a true effect of an exposure on an outcome under investigation or there might be an alternative explanation to the effect shown. This alternative explanation may be due to chance (random error) or due to bias and/or confounding (Hennekens and Buring, 1987).

Bias: Bias can be generally defined as an error that occurs in the design and/or execution of a study that produces distorted results affecting its validity (Ranstam, 2008). This is an issue of concern in observational studies since they only allow the passive observation of events occurring anyway without direct intervention or manipulation that is typically used in experimental studies. True experimental designs involve random allocation of participants to conditions, blinding of participants/patients/physicians (e.g., to study aims, group allocation etc.), rigorous examination and strict follow-up etc., all of which are steps that increase validity and reduce bias. In such cases (e.g., RCTs), where validity issues have been dealt with during the design and conduct of a study, statistical analysis can focus on statistical precision for valid results. However, in observational studies, statistical analysis is much more complex since it also has to account for lack of rigour due to the design/conduct of an observational study that does not involve direct intervention. Therefore, while analysing relationships/associations/causation in an epidemiological study, the effects of potential bias needs to be understood and accounted for when inferring results and making conclusions. Bias is therefore, the lack of internal validity (Lu, 2009) or the incorrect assessment of association between an exposure and the outcome in the population under study (Boyko, 2013). Hennekens and Buring

(1987) defined bias as any systematic error in an epidemiological study that results in an incorrect estimate of the true effect of an exposure on the outcome of interest.

Depending upon the direction of the systematic error, the bias effect will make an estimate either above or below the actual value of predicted effect of the exposure. There can be very little done to adjust for this bias at the analysis stage, therefore it is crucial to control the ways by which bias may be introduced during the stage of design and conduct of a study. Careful consideration early on will limit the harmful effects on the validity of a study and its results (Weiss & Koepsell, 2014).

Information and selection bias are the most common types of bias in epidemiological studies (Hennekens and Buring, 1987; Jurek *et al*., 2005; Ranstam, 2008). An error that is introduced when a study population does not represent its target population causes selection bias. Such errors can be introduced at any stage such as during study design (incomplete or wrong definition of an eligible population, uneven diagnostic procedures in target population, or inaccurate sampling frame), and study implementation (Ellenberg, 1994; Kleinbaum, 1981). Selection bias occurs at the stage when subjects enter in to a study, such as bias due to non-participation, or healthy screening. An example would be heavy drinkers or smokers not taking part in a study that aims to explore the relationship between alcohol consumption/smoking with any disease or health outcome (cardiac/lung disorders).

Systematic differences in the way data are collected on exposure and outcome can result in information bias, for example, errors introduced because of observer, interviewer, reporting and recall biases. All of this produces misclassification bias (Delgado-Rodriguez and Llorca, 2004; Jurek *et al*., 2005). Such a misclassification occurs when sensitivity and specificity of procedures to detect exposure or/and outcome are not perfect. This leads to incorrectly classifying exposed participants as non-exposed and vice-versa. Example here A certain degree of such misclassification bias needs to be accounted given that measurement tools to gather data on exposure status or assess outcomes on subjects are very uncommon. Some more examples of information bias include bias due to interviewer/observer (e.g., knowledge of hypothesis, disease, outcome, and intervention status can influence data recording) give example here; recall bias (presence of a disease affecting the perception of causes such as in a cohort study on exposure of hazardous substances where the workers already know that they work in such environments and their exposure and predicted health outcomes, hence tend to recall and report more effects); and, reporting bias (under reporting of socially undesirable behaviours such as drinking or any other addictions).

Confounding: Confounding occurs when a given variable is a risk factor for an outcome among non-exposed populations and is associated with the exposure (Delgado-Rodriguez and Llorca, 2004). Confounding provides an alternative explanation for an association between an exposure and an outcome (Lu, 2009; Carneiro and Howard, 2011). Confounding occurs when an observed association is misleading owing mainly to two reasons: firstly because a correlation exists between exposure and another risk factor; and secondly because the risk factor is also associated with the outcome independent of exposure. As a consequence, the estimated association is not the same as the true effect of exposure on the outcome (Carneiro and Howard, 2011). For a variable to be a confounder, its relation to the outcome should be independent of its association with the intervention (Lu, 2009). In an epidemiological study, a potential confounder is a factor that might have an effect on the risk of disease. It may either have an effect by direct causal link to the disease, or through proxy measures for other unknown causes, such as age and socioeconomic status (Carneiro and Howard, 2011). Confounding is often illustrated as a common causal pathway between exposure/intervention/treatment and the outcome/effect. It is a significant threat to the validity of study results in non-experimental/observational studies (Velentgas *et al.,* 2013). For instance, in a study exploring the association between smoking and oral health status of a population cohort, other variables such as gender and lower socioeconomic status (SES) may act as confounders and distort the study results and its validity. An example for this is the secondary analysis of the ELOHI data study for East-London people where lower socio-economic status and male sex was strongly associated and acted as confounders when exploring the association between smoking and oral periodontitis (Anjum *et al*., 2020).

Reliability, Validity and Generalisability: Reliability and validity are characteristics of outcome measures and are an integral part of the researcher's evaluation and selection of these measures. In an epidemiological study, reliability is the means to produce consistent results and for these results to remain consistent on different occasions (Bowling, 2001), and can also be the degree to which the score of a measure remains constant across different assessors. For example, in a study involving the subjective judgment of two or more assessors, the similarity or their judgments measures the reliability of the assessment data.

Validity, on the other hand, is the degree to which a measure assesses what it is intended to measure. It is the extent to which an instrument, such as a survey or test, measures what it is intended to measure (also known as internal validity). This is required if the results of a study are to be consequential, applicable and relevant (Shantikumar, 2018). Furthermore, to ensure external validity or generalisability, it is a prerequisite to warrant a study's internal validity. The limited generalisability of findings from experimental studies (such as RCTs) is one of the major motivations for the conduct of non-experimental studies (Velentgas *et al.*, 2013). To make population-based decisions, for example, for healthcare organisations providing insurance coverage for a new medical device that has similar alternatives, strong and robust research findings are needed. These organisations will only accept evidence in the form of study results with strong internal validity and generalisability (Smith, 2013). Strong internal validity provides transparency as to how the research is conducted and hence it improves the reproducibility of the research by others. Therefore, potentially increasing the credibility of the study results and findings (Smith, 2013).

External validity is the extent to which the findings of a study can be applicable to other settings and is also known as the generalisability of results. It requires judgment on whether the findings of a study on a sample are applicable to a wider population. Factors such as the characteristics of the participants (defined by demographic and clinical characteristics, source population, response rate, inclusion criteria, etc.), study setting, interventions or exposures investigated must be probed, studied and examined in depth before making inferences about generalisability. Incorrect generalisation threatens external validity of a study. There might be factors within a study that can lead to incorrect generalisation, these include too narrow eligibility criteria of a study that might restrict the general population (Shantikumar, 2018). For example in RCTs, a strict inclusion criterion on population participation (excluding vulnerable groups or ages) leads to decreased generalisability of results.

Causation and Association: Epidemiological studies are principally designed and conducted to evaluate the cause of any disease outcome. Since most of these studies are observational rather than experimental in nature, to conclude a cause-effect relationship between the factors, a number of possible other explanations for an observed association between these factors need to be considered. In other words, causation needs to be distinguished from mere association – the link between two variables (often an exposure and an outcome). An observed association may also have an alternative explanation such as described in the above sections. These might be due to the effects of chance, bias or confounding (Barratt and Kirwan, 2009; Shantikumar, 2018).

Defining causation has been the topic of debate among various scholars and philosophers. However, it is vital that studies exploring causal phenomenon must adopt a working definition for causation. Rothman and Greenland (2005) defined cause of a specific disease outcome as an antecedent event, condition, or characteristic that was necessary for the occurrence of the disease at the moment it occurred. However, this only defines a component of a cause and not a complete causal mechanism. This consists of a set of minimal conditions and events that inevitably produce disease, where minimal implies to all the conditions or events that are necessary for that disease occurrence.

Furthermore, any disease outcome can be caused by more than one causal mechanism. And each of these causal mechanisms involves the joint action of a multitude of component causes. This is multicausality and it is important because most identified causes are neither necessary nor sufficient to produce the disease outcome. This means that neither the presence of a component cause alone will lead to the occurrence of the disease nor the absence of any of the component causes will prevent the occurrence of the disease outcome (Rothman and Greenland, 2005). Another concept in causality is that of reverse causality where an association between an exposure and an outcome is not due to direct causality from exposure to outcome; but rather because the defined outcome produces a change in the defined exposure. For example, if an association is found between recreational drug usage (exposure) and poor mental wellbeing (outcome) in a study, then it might conclude that using drugs is likely to impair wellbeing. However, there might be another explanation to this finding, which is the presence of reverse causation where people with poor mental wellbeing are more likely to use recreational drugs as a means to escape their mental state.

Therefore an observed statistical association between an exposure/risk factor and a disease outcome does not necessarily lead us to infer a causal relationship. On the other hand, the absence of an association does not necessarily imply the absence of a causal relationship. A judgment about whether an observed statistical association represents a cause-effect relationship between exposure and disease requires inferences far beyond the data from a single study. The Bradford Hill criteria are widely used in epidemiology as a framework with which to assess whether an observed association is likely to be causal (Barratt and Kirwan, 2009; Shantikumar, 2018). Hill suggested that in order to conclude causation between variables in any study; some aspects of the relationship between these variables should be considered to distinguish causal from non-causal associations. These were strength, consistency, specificity, temporality, biological gradient, plausibility, coherence, experimental evidence, and analogy (Rothman and Greenland, 2005).

Statistical significance/effect estimates: Effect measures are statistical constructs that compare data on odds ratio and mean difference between two intervention groups (experimental studies) or exposure factors (observational studies), where the odds ratio is a relative measure and the mean difference is an absolute measure (Higgins *et al.*, 2019).

The true effects of any given intervention/exposure are never known with certainty, and can only be estimated by the studies available. This estimate is measured with uncertainty and expressed as a confidence interval or standard error (SE). Estimates of effect describe the magnitude of the intervention effect in terms of how different the outcome data were between the two groups (Higgins *et al.*, 2019). An estimate of effect may be presented along with a confidence interval or a *p*-value. It is usually necessary to obtain a standard error (SE) from these numbers. This standard error will provide information about how accurate is the effect measure such as the mean of a given sample when compared to true population mean. An increase in the value of standard error demonstrates that the means are more spread out; then it is likely that sample mean in an inaccurate representation of true population mean.

5.4 Secondary data analysis

Secondary data analysis in its broadest sense refers to the analysis of data collected by someone else (Boslaugh, 2007). Where as in primary data analysis the same individual/team of researchers design the study and collect the data for analysis. Secondary data analysis includes the examination of data for a research question other than for that which it was initially collected, or for using more advance statistical analysis to further explore the data. There are two general approaches to conducting an analysis of an existing dataset: a research question-driven approach or a data-driven approach. In the data-driven approach, researchers go through the variables in any given dataset and decide what research questions could be answered using them. But in a research question-driven approach the researchers have a prior question or hypothesis in mind and then look for appropriate datasets to address the research question (Cheng & Phillips 2014).

Data that is collected for a different purpose can be employed for achieving the objectives of another study, but this may have limiting consequences. However, while it can provide the user with some benefits too, both the strengths and limitations of such data have to be considered and acknowledged before a secondary data analysis is performed.

5.4.1 Strengths & limitations of secondary data analysis

Researchers must have a comprehensive understanding of the strengths and limitations of a secondary dataset. This can be achieved by obtaining detailed descriptions of the cohort under study, the sampling procedures, response levels, assessment tools, and quality control measures. It is also important to obtain and explore the survey instruments used to collect data and its variables, as well as any codebooks or guidebooks provided. These documents should provide sufficient information to assess the internal and external validity of the data in order for the researchers to decide whether or not the dataset will generate meaningful results and conclusions (Cheng & Phillips 2014). Some of the strengths and limitations of a secondary dataset and its analysis are discussed below.

The most obvious advantage of secondary analysis of an existing dataset is its low cost. It gives access to historical or national/international level data, which would otherwise be very expensive to collect, thus saving on human resources. The process of data collection has already been completed, thus saving time as well as making a study possible in a given time frame such as three years for a PhD.

The datasets very often provide readily available information on a range of measurements and variables that are not necessarily collected for the primary study. Government funded surveys collect a high volume of data through which communities can benefit at large. Using these data to produce results and conclusions for public health issues in turn makes best use of government funded data collection. These data provide better external validity owing to large samples, so it means that the results of the study for which they are used can potentially be generalised to other situations and to other people (Koziol & Arthur 2012).

It also maximises the utility and usefulness of the data collected, making it more efficient, as well as being more ethical to re-use data that will yield more outcomes for the time that participants invested (Cheng & Phillips 2014). The availability of such databases also provides statisticians with real-life data to test new statistical models. Such analyses could identify potential new interventions to existing problems that can subsequently be tested in prospective studies (Cheng & Phillips 2014).

Inherent to the nature of secondary data analysis is that the data that has been collected is for an original purpose, therefore it may have some information unavailable for the purposes of the secondary data analysis if the research questions are very different. All the more, this data might not have all the information for population subgroups or for all the geographic regions of interest (Cheng & Phillips 2014). Sometimes to protect the confidentiality of data respondents, identifying variables such as ethnicity, specific age, post-codes etc. may be deleted from public or secondary use. This can cause residual confounding where the omitted variables are crucial covariates to control for in the analysis. The researchers conducting secondary analysis are not usually the same individuals as those involved in the data collection; therefore, they are mostly unaware of study-specific issues in the data collection process that may be important to the interpretation of specific variables in the dataset (Cheng & Phillips 2014).

There may also be scarcity in information regarding the study design and data collection procedure of the secondary dataset. This may bring up issues such as internal/external validity, comparability or generalisability of the data. The data, if collected, on a different population and used to answer a different research question, can complicate results and inferences (Koizol & Arthur 2012). Moreover, large datasets may potentially lack depth, and this should be understood while making associations and generating results. Such lack of depth needs to be reported while making conclusions (Koizol & Arthur 2012). Therefore, before making conclusions and generalising results, these issues must be taken into consideration. Finally, secondary data stored ready for analysis, can be in various formats; hence it requires a good knowledge of survey statistics to maximise the potential of the analysis (Koizol and Arthur 2012).

6. METHODS

6.1 Introduction

This is an epidemiological prospective cohort study, drawing on secondary data from the MOBILIZE Boston Study (MBS) dataset. It focuses specifically on socio-demographic factors, pain outcomes, and social networks and activities data to identify if any relationship exists between social networks and pain outcome in community dwelling older people. This chapter introduces the MBS study and its dataset, before outlining the methods used in this thesis, including the research hypotheses, study variables, characteristics and analyses conducted.

6.2 Mobilize Boston Study

The MOBILIZE Boston Study (MBS), "Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston", is a prospective cohort study funded by the National Institute on Aging (Leveille *et al.,* 2008). Leveille *et al*. (2008) describes the Mobilize Boston Study design and methods in detail, and provides an important new data resource for examining novel risk factors for falls and mobility problems in the older population.

The need to explore pain and the risk of falls formed the basis for the MBS. There are several risk factors for falls that are not well understood, such as pain, changes in cerebral blood flow regulation, and foot disorders, for example. This is partly because they pose challenges in measurement particularly for large observational studies (Leveille *et al*., 2008). There have been few studies that demonstrate that location of pain throughout the body is an important predictor of falls and disability (Leveille *et al*., 2001; Leveille *et al*., 2002). Some studies have demonstrated that postural blood pressure declines are associated with falls as reported by Leveille *et al*. (2008) but it is still not clear whether changes in cerebral blood flow (CBF) regulation may contribute to falls in community-dwelling old people. Another important and often overlooked risk factor for falls is foot disorders. The MBS aimed to better understand these predictors of falls. However, it was designed to efficiently address multiple project aims since it collected information on numerous variables that included both clinical and non-clinical data by using core resources such as a team of experienced researchers, clinical research nurses, as well as time and money to recruit and study a large population of individuals, aged 70 years and older. Furthermore, the identification and careful characterisation of a diverse, elderly, community-based population enabled the creation of a valuable database to foster future research beyond the scope of the MBS (Leveille *et al.*, 2008).

Therefore, the MBS dataset that is used for this study could be regarded as both research question driven, and data driven. This is because the study aim was mainly to examine novel risk factors for falls and mobility problems (research question driven) in the older population. But, since it collected information on various clinical and non-clinical variables in older people (data driven), it can address many other project aims.

The MBS data codebook contains all the information on the measures used, with details of variables on selection, definition and measurement criteria explained. This was prepared by the principal investigator Lewis Lipsitz and includes the description of the study, sources of data, data collection, naming and editing, data entry and verification, and handling instructions. It also has detailed variable information and a variable definition sheet, along with all the associated codebooks and forms (Research Nursing Home MBS data codebook, 2008).

There have been four studies published using the MBS to date. The first study was a research article on the methods and design of the prospective cohort MBS and novel risk factors for falls (Leveille *et al.*, 2008), and the second was on chronic musculoskeletal pain and occurrence of falls (Leveille *et al.*, 2009). This study demonstrated that chronic pain measures such as number of locations, severity, or pain interference with daily activities was associated with greater risk of falls in older adults. A third study using the MBS dataset investigated the management of persistent pain in older adults, finding that only one third of the MBS participants reported using the pain management strategies consistent with guidelines (Stewart *et al.*, 2012). A fourth study explored the pain characteristics associated with the onset of disability in older adults, concluding that older adults living in the community suffering from chronic pain in multiple musculoskeletal sites have a greater risk for developing disability over time and consequential decline in clinical mobility performance when compared to those without pain (Eggermont *et al.*, 2014). All of these studies revealed that older adults suffer from chronic pain, falls, functional disability and problems in managing their pain.

6.2.1 Study design

The MBS was based in the Institute for Aging Research (IFAR) at the Hebrew Senior Life, a large geriatric housing, health care, and research organisation in Boston, USA. The MBS was a collaborative effort involving investigators at IFAR, Beth Israel Deaconess Medical Centre, Harvard Medical School, the University of Massachusetts Boston (UMASS), and Boston University. The population-based recruitment was conducted by the UMASS Centre for Survey Research (CSR) in close collaboration with IFAR's outreach staff. Study operations were centralised in the Institute where the staff coordinated all aspects of participant enrolment, data collection and management, as well as participant follow-up (Leveille *et al*., 2008).

Once recruited through home visits, participants were contacted by telephone by the IFAR research staff to confirm eligibility and schedule the two-part baseline data collection, which included a home visit, and an examination at the MBS research clinic based at IFAR. The data collection was repeated at 18 months following enrolment, using the same two-visit approach.

6.2.2 Study participants

6.2.2.1 Participant selection

In total, the MBS recruited 765 participants by January 2008, all of which had completed the two-part baseline assessment. The selection strategy used, targeted older adults aged 70 years and above living within a five-mile radius of IFAR. The IFAR used a simple random sample of older people from the town lists, which consisted of information about the various populated places, cities, towns, villages and its people, demographics and other information. A comparison of the demographics of persons on the town list used by IFAR with the US Census 2000 showed that the list had a comparable distribution by age and sex in the age group of 70 and above (Leveille *et al.,* 2008).

The geographic boundary, chosen to facilitate recruitment and limit transportation burdens and costs, included a wide variety of neighbourhoods in Boston and surrounding areas ranging from ethnically and socioeconomically diverse urban communities to suburban regions with predominately white, middle-class residents. According to the U.S. Census 2000, among persons aged 70 and older in this locality, the minority representation was approximately 19%, which was lower than the general Boston population across all ages (Leveille *et al*., 2008).

The criteria for eligibility for the MBS included being aged 70 years or older, ability to speak and understand English, ability to walk across a small room, sufficient vision to read written material, and the expectation that they will be living in the area for at least two years. Spouses/companions aged 65 or older living with a participant were allowed to join the study as it was recognised that recruitment of one spouse or companion without the other would limit participation. Inclusion criteria for the MBS included English-speaking participants only because it was not feasible to translate the study instruments and conduct the interviews in the many languages that were spoken within Boston's minority communities (Leveille *et al*., 2008). This is a limitation of the study imposed due to practical and financial constraints.

Furthermore, the exclusion criteria consisted of any terminal disease condition, severe hearing and vision loss and MMSE score ≤18. This was deemed necessary, as participation required the maintenance of a falls diary, the filling in of questionnaires, the visiting of a research clinic, and telephone conversations. Participation for these individuals would therefore be difficult, with those with a terminal illness either not being well enough or not available for the study’s follow-up period. At the home interview, the research assistant would establish whether participants were free from severe visual or hearing deficits (via hearing tests), and whether they suffered any serious language difficulties. Table 6. 1 demonstrates the eligibility (inclusion & exclusion) criteria for screening.

Table 6. 1 MOBILIZE Boston study eligibility criteria

Inclusion criteria	
Age	70 years or older (65 if living with an eligible MBS participant)
Language	Able to understand and communicate in English

Residence	Plans to live in the same area for two or more years
Mobility	Can walk 20 feet without personal assistance (walking aids allowed)
Exclusion criteria	
Disease	Terminal conditions
Health condition	Severe vision/hearing deficits
Cognitive function	MMSE score <18

6.2.2.2 Participant screening and recruitment

Among the 5655 households selected for recruitment, 4319 people aged 70 and older were identified as eligible. However, for those identified, the eligibility criteria was applied and 1610 were deemed ineligible. The primary reasons for ineligibility was language other than English and residing in a nursing home. 1916 were of unknown eligibility (e.g. refusal to complete screening), 44 were eligible, however, did not complete the interview. A total of 749 were deemed eligible and completed both the baseline home interview and the clinical examination (Leveille *et al.*, 2009).

After recruitment, the baseline-testing phase commenced with the administration of screening tests as part of an interview conducted in the participants’ homes. Participants’ ability to perform the various tasks that were part of the MBS protocol was precluded by presentations of any severe sensory deficits and moderate or severe cognitive impairment (Leveille *et al.*, 2008). The Mini-Mental State Exam (MMSE) scale (Folstein *et al.* 1975) was used to screen the cognitive abilities of the MBS participants. Participants with a MMSE score less than 18, indicating moderate or severe cognitive impairment, were excluded (Leveille *et al.*, 2008). The MBS used race and education adjusted cut points to decide for moderate to severe cognitive impairment based on the study by Escobar *et al.* (1986) on use of MMSE in a community population of mixed ethnicities.

6.2.3 Data collection

Both the in-home interview and clinic examinations were a part of the data collection procedure, which were designed to meet the aims of the MBS project. They aimed at collecting extensive information that comprised of examining a set of novel risk factors for falls. Keeping in mind the multivariable analyses, information on descriptive variables, covariates and the standard set of established fall factors were obtained. The burden of data collection on the participant was kept to a minimum in an already lengthy collection procedure by collecting information on carefully selected optimal measures (Leveille *et al*., 2008).

The interview conducted at baseline required approximately three hours. The in-clinic appointment, conducted by research nurses, also lasted for approximately three hours and took place within four weeks of the home visit. Incentives in the form of $15.00 for each home visit and $30.00 for the clinic appointment were given to the participants. Commercial transport vans were provided to all participants for transportation to the MBS clinic if needed or requested (Leveille *et al.,* 2008).

6.2.3.1 Baseline home interview

Trained research assistants conducted the baseline home interview collecting information on health and functioning. These included chronic diseases (self-report of physician diagnosis and the Rose Angina and Claudication Questionnaires), health behaviours (smoking, alcohol use, walking activity), self-efficacy for pain and disease management, social network and support, pain assessment, fall history, fracture history, medication adherence and socio-demographic characteristics. Three domains of disability were assessed, Activities of Daily Living (Katz *et al*., 1963 as cited in Leveille *et al.,* 2008). (ADL: bathing, dressing, transferring, using the toilet, and eating), Instrumental Activities of Daily Living (Lawton and Brody, 1969 as cited in Leveille *et al.* 2008) (IADL: shopping, preparing meals, and housework), and lower extremity mobility (Rosow and Breslau, 1966 as cited in Leveille *et al.* 2008) (walking and stair-climbing) (Leveille *et al.* 2008). Individuals were asked to identify the level of difficulty (0=none, 1=a little/some, 2=or a lot or inability), in performing each activity (Leveille *et al*., 2008).

6.2.3.2 Baseline clinic examination

The baseline examination at the IFAR clinical research centre was conducted by experienced research nurses trained in the administration of clinical and performance measures. Various domains of health were covered in the baseline clinical examinations. The intensive assessment was carefully done without rushing and allowing for rest periods. This was to prevent excessive burden on the MBS participants (Leveille *et al*., 2008).

The MBS dataset is wide and extensive and contains information on various measures of interest and variables that are beyond the scope of this study. Therefore, only those MBS variables required for answering the research questions of this study are described in the following sections.

6.2.4 Variables of the MBS

6.2.4.1 Assessment of cognitive function

Verbal memory functioning of the MBS participants was assessed with the Hopkins Verbal Learning Test – Revised (HVLT-R - Leveille *et al*., 2008). The HVLT-R is a 12-item word-list learning test that has been identified as an ideal memory measure for older people suspected of dementia (Shapiro *et al.* 1999). It is both reliable (Benedict *et al*., 1998) and holds validity for older adults (Shapiro *et al*., 1999). It is popular mainly because it is brief, well tolerated by geriatric and patients with dementia, and has six alternate forms. The list is read to subjects on three successive learning trials. Free recall scores are recorded for each trial. A yes/no recognition task immediately after the third trial is presented. Subjects are then asked to identify all target words by responding ‘yes’, and to reject 12 non-target words by responding ‘no’. A key limitation of the HVLT is its lack of a delayed recall trial. The revised version of HVLT included 20-25 minutes of delayed recall trial, a measure of forgetting, and a delayed recognition trial. In their study, Benedict *et al.* (1998) demonstrated that their revised version (HVLT-R) had acceptable reliability. The test forms were equivalent with respect to learning and delayed recall, with some moderate inter-form differences on delayed recognition task.

Cognitive status was assessed using the MMSE instrument, which is a 30-point questionnaire (Folstein *et al*., 1975), scored out of 30 (Leveille *et al*., 2009), with lower scores indicate greater impairment. MMSE offers to gauge cognition where an interviewer asks 17 questions. These questions cover a broad set of cognitive domains: orientation, registration, short-term memory, attention, calculation, visuo-spatial skills, and praxis. Although it was designed to aid clinicians, it gained popularity and has been used in clinical and therapeutic research, community settings and longitudinal studies (Burns *et al*., 1998). It has been used widely in prevalence surveys to identify individuals with a high probability of being demented. It was adopted as the core cognitive measure in the European group of incidence studies of dementia (Burns *et al*., 1998). There are no specific cut-off points for clinical diagnosis, however 17/18, 22/23, and 24/25 have been used by several studies in the literature for severe, moderate, mild cognitive impairments (Brayne and Calloway, 1990 as cited in Burns *et al*., 1998). The MMSE cut off threshold for the current study participants is described under health factors in the section 6.3.4.1.

6.2.4.2 Assessment of chronic pain

Several measures were used to assess pain location, intensity and characteristics during the health interview. The Brief Pain Inventory (BPI) scale is multidimensional consisting of three subscales that include two pain descriptors, pain-related quality of life, and pain relief (Cleeland 1989). The four-item pain severity sub-scale of the BPI measures pain intensity over the past week using a 0–10 numeric rating scale, where 0 was for no pain and 10 for severe or excruciating pain, or as bad as one can imagine. Level of pain interference (with general activity, mood, walking, normal work including housework, relations with other people, sleep, and enjoyment of life) was measured using the seven-item BPI pain interference sub-scale. Response levels on the numeric rating scale ranged from 0 (‘does not interfere’) to 10 (‘completely interferes’).

6.2.4.3 Assessment of disability & performance outcome

Three domains of disability were assessed at baseline and follow-up: mobility in walking (walking for one-quarter of a mile, ~two or three blocks) and stair-climbing (walking up 10 steps, or one flight of stairs), activities of daily living (ADLs: bathing, dressing, transferring, using the toilet, and eating), and instrumental activities of daily living (IADLs: shopping, preparing meals, and light and heavy housework). Four response options are able to identify the level of difficulty in performing (none, a little, some, a lot) or inability to perform each activity. Incident disability is defined as the reporting of any difficulty in one or more tasks within a disability domain at the follow-up assessment in persons who had no difficulty in that specific domain at baseline (Leveille *et al*., 2008; Eggermont *et al*. 2014).

Mobility performance was measured using the validated Short Physical Performance Battery (SPPB), which was used to assess lower extremity function in older adults over 71 years of age (Guralink *et al*., 1994). The study by Guralink *et al*. (1994) provided evidence that performance measures can validly characterise older persons across a broad spectrum of lower extremity function. The SPPB comprises three sets of lower body mobility tests: gait speed, standing balance, and repeated chair stands. Gait speed was assessed as the faster of two trials of a timed usual-pace four-meter walk. Standing balance was assessed in three 10-second stands; standing with feet side by side. Timed repeated chair stand tests measured the ability and time required to stand up from and sit down in a chair as fast as possible five times with arms folded across the chest. The SPPB was scored using a standard scoring protocol, ranging from 0 to 12, with higher values indicating better function. It was calculated from the sum of categorical scores on the three tests, each ranging from 0 to 4. Any decline in SPPB scores were measured by subtracting the follow-up score from the baseline score (Eggermont *et al.,* 2014).

6.2.4.4 Assessment of depression

The Centres for Epidemiologic Studies Depression (CESD) scale is a brief self-report scale designed to assess depressive symptoms in the past week. It consists of 20 items on six sub scales showcasing key facets of depression: depressed mood, feelings of guilt and worthlessness, feelings of helplessness and hopelessness, psychomotor retardation, loss of appetite, and sleep disturbance (Radloff, 1977). This instrument has been used in previous studies (Berkman *et al*., 1986; Yesavage *et al*., 1982) and has been found to be valid, reliable and sensitive to change in older populations. Radloff (1977) reported high internal consistency with Cronbach's alpha coefficients ranging between 0.85-0.90 across studies. Researchers (Eaton and colleagues) at the Johns Hopkins University developed a revised version of the CES-D, namely the CESD-R. The revised version has symptoms and response options added together (Eaton *et al.,* 2004) that satisfy symptoms and duration criteria for major depression.

The CESD-R was used in the MBS, the extent of depression was calculated using item response theory. The metric was set relative to the mean and variance of the MBS sample aged 70–74 years at baseline interview using a mean of 50, standard deviation of 10. To classify minor and major depression, a diagnostic algorithm was applied. Participants with either minor or major depression had to have either anhedonia or dysphoria to be classified as having depression. Participants with minor depression had to present two of nine symptom clusters (dysphoria, anhedonia, appetite disturbance, sleep disturbance, difficulty thinking, guilt, fatigue, psychomotor retardation, or suicidal ideation), whereas major depression required presentation of five of nine symptom clusters. Symptoms within clusters had to be present nearly every day for two weeks in the previous month to meet the duration criteria (Leveille *et al*., 2008). In an initial sample of 600 MBS older adult participants, the items that comprise the CESD- R were highly internally consistent with a coefficient alpha = 0.87 (Leveille *et al*., 2008).

6.2.4.5 Assessment of socio demographic factors

The following socio-demographic characteristics were assessed at the home interview: age, sex, race (self-identified), and years of education. Age was recorded both as a categorised and continuous variable in the MBS. Sex was dichotomised as male and female. Race had seven different categories, which were, Black African-American, White, American Indian Alaskan, Asian, Hawaiian Pacific Island, Some other group and Multi-racial. Lastly, education had twenty-one different categories. These categories were school dropouts and no-schooling (-1 and 0 respectively), grade one to grade six (1-6), grade seven to grade twelve (7-12), first and second year of college completed (13,14), third and fourth year of college completed (15,16), first and second year of university completed (17), third year of university completed (18) and trade and vocational (51).

6.2.4.6 Self-administered questionnaire-assessment of social network factors

The self-administered instrument (questionnaire) was handed over to participants at the end of the home interview to complete and bring along with them to the clinical visit. It consisted of questions on social network factors that included a validated measure of social networks (Glass *et al*., 1997), anxiety subscale of the Hospital Anxiety and Depression Scale [HADS] (Zigmond and Snaith 1983; Herrmann 1997), the Physical Activity Scale for the Elderly [PASE] (Washburn *et al*., 1993), and the Short Form-12 to measure self-rated health, bodily pain, limitations in social and physical activities, and emotional health (Ware *et al*., 1996).

The four dimensions and a summary index of social network was proposed and developed by Glass *et al*. (1997) by combining the indicators of structure of network (number and proximity of ties, reciprocity), and indicators of network function (frequency of non-visual and visual contact, feelings of closeness). They tested and confirmed its reliability and validity in their study on a cohort sample of 2812 non-institutionalised men and women age 65 and older living in New Haven, Connecticut (US) from the Establishment of Populations for the Epidemiologic Study of the Elderly programme (EPESE), initiated by the National Institute on Aging (Glass *et al.,* 1997).

Anxiety was measured using the Hospital Anxiety Depression Scale, which was found to be acceptable, reliable (Cronbach's alpha = 0.8-0.93) and internally consistent value (Herrmann 1997). Retest reliability with HADS showed a high correlation after up-to two weeks, then decreasing with longer intervals. Although HADS theoretically allows for discrimination between anxiety and depression, in reality there is some overlap. However, the review by Herrmann (1997) added that the correlation between HADS anxiety and depression subscales were mainly due to a real coincidence of anxious and depressed symptoms in the patient groups and only to a lesser extent to inadequacies of the instrument. In terms of absolute values, correlations of both HADS subscales with their corresponding criteria were satisfactory or good (Herrmann 1997).

The Physical Activity Scale for Elderly (PASE) is a brief, easily scored, reliable and valid instrument for the assessment of physical activity in epidemiologic studies of older people (Washburn *et al*., 1993). This instrument was evaluated in a sample of community-dwelling older adults; and the test- retest reliability, assessed over a 3-7-week interval, was 0.75 (95% CI = 0.69-0.80). This was used to quantify the level of activity in the MBS participants in the previous seven days. At the end of the home interview, all MBS participants were given this battery of questionnaires to complete and bring with them to the clinic visit (Leveille *et al*., 2008).

6.3 Secondary data study design

The study presented in this thesis employed a secondary data analysis of the existing dataset from the MBS. The MBS dataset and all the information on the variables used for this study were extracted from a published MBS design and methods paper (Leveille *et al*., 2008), and the data codebook (Research Nursing Home MBS data codebook, 2008), both of which were provided by the primary researcher involved in the MBS, and the external advisor to the current study, Professor Leveille. The strengths and limitations of conducting secondary data analysis have been outlined previously (methodology chapter section 5.4.1). The MBS provides information on variables that are required for answering the research questions of this study and thus this data was deemed appropriate to help achieve its aims and objectives. This approach also saves time and costs as well as providing a large dataset and information on many variables. The whole process of data collection for such a large cohort population on so many different variables for this study was not feasible within the timeframe of a PhD. Therefore, using the MBS dataset for the analysis, was preferable to conducting a new study for collecting all the required data.

This study aimed to identify associations between baseline social network/activity and pain outcomes and at 18-months follow-up in older adults. A cross-sectional design was employed to identify if there was any association between social networks/social activity and pain outcomes (severity and interference) in older adults using the baseline MBS dataset. Additionally, the second wave of data on pain outcomes at 18-months follow-up was analysed to see if there was any influence of baseline social networks/social activity on pain outcome over time in this population.

6.3.1Study characteristics and steps in analyses

To conduct this research question-driven secondary analysis of an existing MBS dataset, the first step in the analysis was to run frequency tables and cross tabulation of all the variables that were included in the study (Cheng & Phillips, 2014). Therefore, the first analytical step was to describe the characteristics of the study cohort in order to gather information on the coding patterns of all variables such as (social network/activity, pain outcomes both severity and interference, socio-demographic and health factors), and the missing data profile of each one of the included variables (Cheng & Phillips, 2014).

The second step was to investigate whether cohort characteristics (socio-demographic and health factors) had any relationship with the independent variables of the study. This analytical step was important to understand the effect and the potential influence of covariates on social network/activity, in turn affecting pain outcomes; identifying the potential confounders in this study.

The third step was to examine whether the independent and dependent variables of the study were correlated, before conducting regression analysis, to give an indication of the direction and magnitude of relationships between the variables of interest of the study and identify any potential confounding variables.

The fourth step examined whether there were associations present between baseline exposure (social network/activity) variables and pain outcomes of the study cohort; and whether this association was significant even after adjusting for other covariates and potential confounders. This analytical step aimed to answer whether having higher scores on social network and activity scales could lessen the burden of pain outcomes in older people even in the presence of other covariates.

The final step was to detect an association between baseline exposure (social network/activity) variables and pain outcomes at follow-up, to identify whether having larger social networks and higher social activity scores at baseline lessened the pain outcomes in its severity and interference with daily activities in older adults at baseline, and 18-months later. See figure 6.1 for a schematic diagram of the analytic steps.

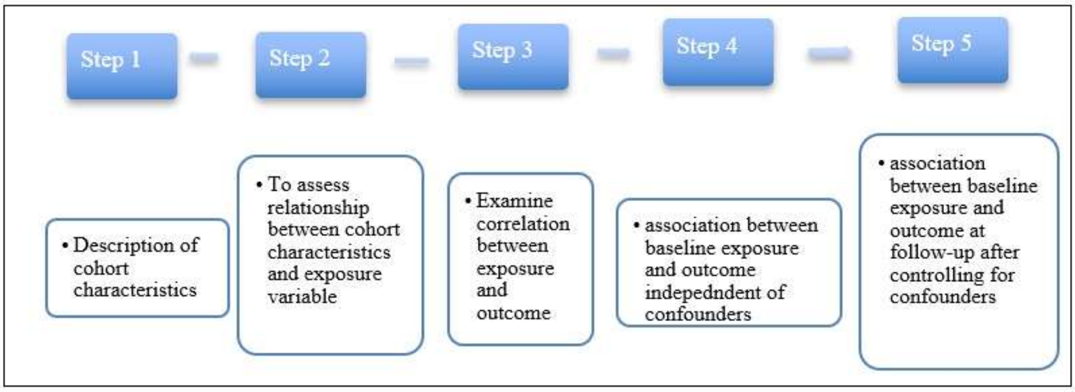

Figure 6. 1 Steps in statistical analyses- Steps in Statistical analysis. Step 1: describing cohort characteristics. Step 2: assessing relationship between cohort characteristics and exposure. Step 3: examining correlation between exposure and

outcome. Step 4: baseline independent association between exposure and outcome. Step 5: independent association between baseline exposure and outcome at follow-up.

6.3.2 Study participants

There were 749 participants who formed the population sample for this study, age ≥70 years at baseline. However, the MBS included a further 16 participants aged 65 years and over, making a total 765 participants. This analysis did not include the data on the 16 participants aged 65-70 years due to the inclusion criterion of 70+ years for eligibility.

6.3.3 Ethical approval

The MBS project was reviewed and approved in 2009 by the University of Massachusetts Boston Institutional Review Board, Assurance # FWA00004634. After establishing that the data gathered in the MBS was suitable for this study, access to the MBS dataset was granted. There was an official requirement to fill an MBS data repository request form to the MOBILIZE Boston Executive Committee review before physically acquiring the data for the current study. However, to gain complete access, it was mandatory to complete an online CITI programme that provided a course on Biomedical Research Training affiliated with the University of Massachusetts Boston (ID: 525). After completing the course and passing an online exam, a CITI completion report was awarded which enabled permission to use the MBS data for the study.

The data, which was otherwise confidential and kept in records at the Hebrew Rehabilitation Centre and UMASS Boston Institutional Review Board with the staff and researchers involved in the MBS, was accessed and examined by the external advisor (Suzanne Leveille). Following an initial examination of the data with my supervisor from the University of Greenwich and external advisor, Professor Leveille from UMASS Boston, who herself has been involved in the MBS and its various projects, potential research questions of this study that would be addressed using this data were discussed.

Further ethical approval for the current research project was not required, as participants of the MBS had agreed for all data to be used in further research and projects when required. During the baseline home visit, the interviewer obtained informed consent from the participant. The participant reviewed the study procedures, including instructions for completing the monthly fall calendars. All the data received was kept confidential and for the sole purpose of the current study.

6.3.3.1 Independent and dependent variables

Based on evidence provided by the literature search (Peat *et al*., 2004; Leung *et al*., 2015); Richardson *et al*., 2015; Lee *et al*., 2016; Hung *et al*., 2017; and Musich *et al*., 2020), it was hypothesised that exposure to a larger social network and higher levels of social activity and greater levels of social support are associated with better pain outcomes in older people. The study predictions are based on findings from the literature that both network structure/characteristic, and social activity will be significantly associated with lesser pain outcomes such as lower ratings of severity and interference in daily activities in older people. Both social network and activity were used as exposures of interest, or independent variables, in the analyses to explain the positive role of social network/activity on pain severity and interference. Pain severity and pain interference with daily activities were both used in the analyses as outcome (dependent) variables.

6.3.3.2 Covariates

Variables known to be related to the study variables, such as socio-demographic variables (e.g., age, sex, years of education) and health characteristics (e.g., mobility difficulty, SPPB score) were controlled for while testing for an association between the independent variables and pain outcome measures in older people. These variables were suggested to act as potential confounders in the current study analysis since there is evidence in the literature of their association with social networks (Peat *et al*., 2004; Escobar-Bravo *et al*., 2012; Leung *et al*., 2015; Hung *et al*., 2017; Musich *et al*., 2020), and various pain outcomes (Jakobsson *et al*. 2003; Peat *et al*. 2004; Leung *et al*. 2015; Docking *et al*. 2014; Hung *et al*., 2017; Musich *et al*., 2020). A chi-square analysis was conducted to confirm if these variables (such as age, sex, education, mobility difficulty and the SPPB score) were associated with any of the study variables, which could indicate potential confounding effects. Any significant associations between covariates and the variables of interest led to inclusion of the covariate in the hierarchical regressions on pain outcomes.

6.3.3.3 Missing data

Information on complete datasets for 749 participants was available in terms of variables used in the analyses. For those participants with missing values on one or more pain outcome variables (*n* = 1), cases were excluded list wise. Imputing missing values was not deemed necessary given that missing values for any given variable of interest did not exceed 1%. Data was available for all the 749 participants for social network variable with just above 1% missing data identified on social activity scores (*n* = 9). This was again due to the way the variable was defined and calculated in the MBS. Social activity score was calculated as a sum of eight questions, each of which had a score of 0 (no) or 1 (yes). For those participants whose answer to four or more of these questions was a 0 (no), the social activity score was categorised as missing for that participant.

For the variable BMI, less than 3% data was missing for participants (*n* = 18). The reason for missing data on this variable was the definition of included participants within a specified BMI category. Those with BMI <10 and BMI >60, were given a missing value category in the MBS dataset. The upper and lower limits of the BMI were defined by the researchers and the data collection team of the MBS with no specific reason or clear notes provided in the MBS data code book; therefore it became a limitation of this secondary data analysis. However, this variable was only used in describing the cohort of current study and not for any advanced analyses. Therefore, the missing data was not deemed problematic for the current analyses.

6.3.4 Data preparation

After obtaining the dataset for this study from the MBS, it was prepared to enable statistical analyses to be conducted in order to test the study aims and objectives. Both, the MBS excel sheet and MBS data codebook were examined to understand and confirm the variables, their labels, and how they were defined and coded in the MBS, whilst recoding to make them suitable for analysis in the this study where necessary. These variables were then systematically formatted for the study by arranging baseline and follow-up data into separate columns in order to facilitate statistical analysis in IBM SPSS Version 25 (2017) statistics.

6.3.4.1 Variables prepared and re-named for the current study analyses

The variables that required further processing for this study's analyses were socio-demographic, health, social network/social activity and pain outcomes.

Socio-demographic Factors: Measures of socio-demographics were age, sex, race and years of education. Age was available both as a continuous and categorical variable in the MBS dataset. For the description of the participant characteristics, age was defined as a categorical variable named 'newagecat' for descriptive analysis, divided into three different categories (70-79, 80-89 and 90-99 years of age) similar to the MBS. However, the continuous age variable 'age-count' was used for advanced analyses such as linear and hierarchical regressions. Sex was used in the data analysis as a dichotomous variable (male or female, where male was coded as 1 and female was coded as 2). The variable 'race' in the MBS dataset had seven different categories, which were, Black African-American, White, American Indian Alaskan, Asian, Hawaiian Pacific Island, Some other group and Multi-racial. The largest groups of people in the MBS data set were white followed by black African-American with very few other races, therefore this served as a rationale to re-group the existing variable into a new variable, 'racecat', with three categories (White (coded as 1), Black (coded as 2), Others (coded as 3)), in line with other studies that have used the MBS dataset (Leveille *et al.*, 2009; Stewart *et al.*, 2012).

The last variable used for socio-demographic characterisation of the cohort was years of education. For the purpose of this study it was re-grouped into three new categories from the existing twenty-one categories (health interview (hi) question-408 for education), in the MBS dataset. These new categories for years of education, which was renamed as 'educat' for this study were 1) less than high school, did vocational and trade 2) high school graduate 3) college graduate, this is in line with other studies that have used the MBS dataset for their analyses (Leveille *et al.*, 2009; Stewart *et al.*, 2012).

Health Factors: the health characteristics of the cohort were described by using measures such as BMI (Body Mass Index), SPPB and a mobility difficulty score. SPPB stands for Short Physical Performance Battery score and measures the lower extremity mobility performance (Eggermont *et al.,* 2014). BMI, mobility difficulty and SPPB scores were measured and represented as a count as well as categorical variables in the MBS dataset.

The MBS dataset divided BMI into three categories of <25 (healthy weight), 25-29 for overweight participants and ≥30 which stood for those participants who were obese. Stewart *et al.* (2012) used this categorical data on BMI for their study analyses to describe the prevalence of pain management approaches used by older adults with persistent pain, and identified characteristics associated with the use of these approaches. They found significant differences in the use of pain management strategies according to demographic and health characteristics of the participants. Female sex, poor health, mobility difficulty, pain severity and interference were more likely to be associated with using more pain management strategies.

A mobility difficulty score was used to assess the lower extremity mobility-range of a participant. Mobility difficulty was measured as a categorical (mobdifcat) variable, those with some difficulty in walking a quarter of a mile or climbing a flight of 10-stairs and those with no difficulty in doing so. The dichotomous data was used for the current study analysis.

The SPPB score was divided into two categories ≤9 which meant poor lower extremity mobility and >9 for normal range of lower extremity mobility in the MBS. This is a common cut-point for poor performance of mobility used earlier by Guralink *et al.* (1996). A study by Stewart *et al.* (2012) used the categorical data on SPPB score for its analysis.

There were also variables for depression and cognitive function that were used to represent the health factors for this study's descriptive analyses. Depression was categorised in the MBS into two categories, No (coded as 1) and Yes (coded as 2) using the CESD-R scoring (Leveille *et al.*, 2009). Cognitive function was screened using the MMSE (Mini Mental Scale Examination score) instrument. MMSE scores were used to indicate the levels of cognitive impairment for the participants, scored 0-30 (Leveille *et al.*, 2008). For the MBS participants, it had a continuous range between 18-30 and measured cognitive functions such as knowledge of time and place, basic motor skills and language use and comprehension. However, for their descriptive analysis, it was dichotomously categorised (No impairment/Yes impairment). MMSE scoring has been used in many studies done in community settings and a variety of cut-points have been suggested (17/18, 22/23, 24/25) by different studies depending upon the appropriate level of its population (Burns *et al.*, 1998). In the MBS, those with MMSE scores between 18-22 were grouped as having some cognitive impairment and those with MMSE scores between 23-30 classed as having no cognitive impairment.

Social network factor: Social networks for MBS participants were measured using a set of nine questions asked in the health interview (hi) questionnaire. This social network measure was based on the Glass *et al.* (1997) social network index. These nine questions related to having someone or seeing someone in one's social network, and closeness to someone. For the purpose of the current analysis, these questions were grouped into two major types: non-visual and visual social network. This was in line with previous research that has divided the social network variable into structural (non-visual) and functional (visual) by Glass *et al.* (1997), and visual and non-visual by Bassuk *et al.* (1999). In a study on social disengagement and cognitive decline in community-dwelling older adults followed over 12 years, Bassuk *et al.* (1999) constructed a social disengagement index and used it in their study to conclude that social disengagement was a risk factor for cognitive impairment in older people. The current study tried to use this index for scoring its social network and social activity variables and conduct analyses. However, since the current analyses used a secondary dataset, some questions on variable scoring identical to Bassuk *et al.* (1999) were missing and hence had to adapt and do with the scarce information available.

Questions for non-visual network were in relation to correspondence with children through letters or phone calls (weekly, monthly, yearly), and with friends and relatives through letters or phone calls in a year. Questions for visual social network were in relation to meeting face-to-face; children seen weekly or monthly, relatives and friends seen monthly.

For this analysis, questions asked by the MBS team on social network variables, although seeming somewhat similar and in lines with the Bassuk *et al.* (1999) study, lacked some depth. This is usually the case with studies involving secondary data analysis. However, since they coordinated with the Bassuk *et al.* (1999) questionnaire, similar coding as done on the social disengagement index was applied for the data analysis.

The questions regarding number of children (hi399), number of children alive (hi400), number of relatives (hi403), and number of close friends (hi 405) were categorised under non-visual social network. Although these questions do not include questions about any correspondence with these social ties through non-visual contacts (such as phone calls or letters), as in the Bassuk *et al.* (1999) study, they still are non-visual in nature. Hence, they were categorised as non-visual for the MBS dataset used for this study analysis. All the data on non-visual social network were count variables. The responses to these questions were added in Excel to create a sum score, as the data were all count variables. A sum score of responses to the questions was labelled as non-visual social network (NonvisualSN) for this study. They were further dichotomised for cross tabulation analysis.

Questions regarding number of children seen weekly (hi401), number of children seen monthly (hi402), number of relatives seen monthly (hi404), number of friends seen monthly (hi406) were categorised as visual-social network. These were similar to the questions in the social disengagement index (Bassuk *et al.*, 1999), hence coded similarly. All the data on visual social network were count variables; therefore, a sum score was calculated, and the variable, visual social network (VisualSN) was created for data analysis.

An additional question was included that addressed functional social network as mentioned in the social network index by Glass *et al.* (1997). The question (hi407), ‘do you have someone to depend upon’, was a categorical variable. It was a different question presented as categorical data and not as a count, and therefore could not be categorised as one of the questions under non-visual or visual social network. In the MBS, responses were dichotomously categorised as Yes or No, and therefore, it was treated as a separate social network variable for the current analysis.

The network variables (NonvisualSN and VisualSN) were used as independent count variables in the regression analyses. However, for the purpose of descriptive statistics and cross tabulation they were categorised into two groups. If the sum of responses for the non-visual social network was ≥6, it was scored as 1 otherwise 0. This was done in this manner because it has been coded similarly and used in the Bassuk *et al.* (1999) study. Similarly, if the sum of responses for the visual social network ≥3, it was scored as 1 otherwise 0. Bassuk *et al.* (1999) performed scoring for the social disengagement index in their study in similar manner. Where on one hand a score of 1 stood for having a social network and 0 stood for no social network based on author's judgment as it was decided to keep a mean response of more than 1 for both non-visual and visual social network questions.

Social activity factor: Variables for social activity were also obtained. The MBS social activity questionnaire included a set of eight questions. These were sa42) visiting restaurant with a person; sa43) visiting a senior centre; sa44) playing cards/games/bingo; sa45) visiting family/friends; sa46) shooting pool/play golf; sa47) attending church/synagogue; sa48) attending club/group meeting; and sa49) regular social activities. A sum score of all these measures was used to signify the social activity score (socact) for the participants of MBS. However, the responses to these questions were dichotomously categorised as 'Yes' or 'No'. Therefore, the total score was calculated by giving a score of 1 for any 'Yes' answer to these questions and a score 0 for any 'No' answer. Then the total social activity score defined by the variable 'socact' in the MBS was calculated which ranged between 0-8. This final socact variable was used as a count variable in the regression analysis for the current study. However, for the purpose of descriptive statistics and cross tabulation the 'socact' variable was categorised into two groups. It was low or medium for any score from 0 to five, and high for scores from six to eight. Bassuk *et al*. (1999) performed a similar scoring for social activity variable in the social disengagement index.

Pain Outcomes: A multi-dimensional Brief Pain Inventory (BPI) scale was used in the MBS. The BPI scale was first designed to assess cancer pain; however, it is also used for generic chronic pain conditions and it calculates two main scores: severity and interference (Lin and Poquet 2016). The pain severity score is calculated from four items on pain intensity (worst pain in last 24 hours, least pain in last 24 hours, average pain, pain right now), and the pain interference score from seven items on pain interference on daily functional activities (general activity, mood, walking ability, normal work including house work, relations with other people, sleep, enjoyment in life). The participants were asked to give their response on a 0-10 numerical rating scale (0 = 'no pain'; 10 = 'worst pain imaginable'). Responses were calculated as arithmetic means of four severity items and seven interference items for pain severity and pain interference respectively (Leveille *et al*., 2009; Lin and Poquet 2016). The MBS had continuous data named as 'BPIsev' and 'BPIinterf' for these pain measures.

The scores for these pain measures were further divided by the MBS into quartiles [no (0); very mild (1); mild (2); moderate to severe (3)] to create categorical data named as ‘BPIsevgrp’ and BPIinterfgrp’. Leveille *et al*. (2009) and Stewart *et al*. (2012) used this MBS data and these pain measures in their study analyses. The association between chronic musculoskeletal pain and fall occurrence was investigated using categorical data on pain severity and interference variables in the MBS participants by Leveille *et al*. (2009), which concluded that the greatest risk of falls was observed in persons with the highest scores of pain severity and interference. Similarly, Stewart *et al*. (2012) used the categorical pain severity variable to find associations between persistent pain and pain management strategies in MBS participants. The current study also used these categorical measures for its descriptive analysis and for identifying the frequency of the population suffering with moderate to severe pain outcomes. However, the count data on pain outcomes (when used as the study’s dependent variable) was used for regression analysis.

The BPI pain severity variable was the same variable as used in the MBS dataset for this study’s analysis. However, the BPI pain interference measure from the MBS data was re-coded for this study. It was re-calculated from the sum of only six items (general activity, mood, walking ability, normal work including house work, sleep, enjoyment in life) instead of seven items. This was deemed appropriate as the social network/activity variable (which overall measures the older people’s relationship with other people) and one item from the interference questionnaire, ‘relations with other people’, were highly similar. This could artificially inflate the correlation between social networks, which measures relationships with people, and pain interference. Hence, the decision was to recode the pain interference measure using only six items of the BPI pain interference subscale (NewBPIinterf/NewBPIintergrp) for current study analysis. Therefore, the BPI measures used for the current study analysis were count data on BPI pain severity (BPIsev) and categorical data on BPI pain severity, (BPIsevgrp) plus the count data on BPI pain interference (NewBPIinterf) and categorical data on BPI pain interference (NewBPIintergrp).

6.3.5 Study hypotheses

This study aims to find evidence to support the hypothesis that social networks/activity have a positive effect on pain outcomes in older people (≥70). The information gathered from the background literature, the literature review and the conceptual model by Berkman *et al*. (2000) on social networks influencing health outcomes in older people generated specific study hypotheses. To find evidence to support these hypotheses, specific inferential statistical tests were conducted; the results of which are presented and discussed in the results chapter (Chapter Six). These hypotheses were divided into three main types on the basis of the variables they included: between covariates and independent variables, between independent and dependent variables, and between covariates and dependent variables of the study.

Relationship between covariates and independent variable

Age: There is evidence in the literature that an increase in age is negatively associated with social networks, and in particular for contact with close friends and relatives (Peat *et al*., 2004). Therefore, it is assumed that social networks will be smaller, and social activity scores will be lower, with increasing age.

Sex: Females have been associated with more social ties (Leung *et al*., 2015). Therefore, the current study prediction is that females will have larger social networks than male participants.

Education: Better education is associated with greater social engagements (Escobar-Bravo *et al*., 2012), therefore it is predicted that participants with a higher number of years in education will report higher social activity scores.

Functional ability: There have been studies demonstrating the protective effects of social networks and an active social life on disability in terms of ADL/IADL (e.g., Escobar-Bravo *et al*., 2012), hence this current study hypothesises that poorer functional ability (for example lower mobility difficulty) will be associated with poorer social networks/activity.

Relationship between covariates and dependent variables

The literature has established that both increasing age and female sex is associated with pain outcomes (Peat *et al*., 2004; Leung *et al*., 2015). Therefore, it is hypothesised that higher pain severity and interference scores will be experienced in females when compared to males, and with increasing age, in this population. Socio-demographic and health covariates revealed statistically significant relationships with pain interference in the Peat *et al*. (2004) study; hence, this study predicts that these covariates will influence pain outcomes in this cohort population. Therefore, a hierarchical regression analysis will be conducted to control for these covariates and any possible confounding actions when finding associations between independent variables and pain outcomes.

Relationship between independent and dependent variables

Based on research showing that social contact outside the household was associated with lower pain (Leung *et al*., 2015), it is predicted that having a larger visual and non-visual social network will be significantly related to lower pain severity. Also, as demonstrated by Peat *et al*. (2004), social network was associated with lower pain interference, and therefore, the current study predicts lower pain interference in participants with higher scores on the social activity scale and with larger social network ties.

As evidenced by the Leung *et al*. (2015), baseline social networks can have an influence on pain intensity and progression over a period of two years. Therefore, the current study hypothesises a positive role of baseline social network and activity score on pain severity and pain interference at an 18-month follow-up in this cohort. This study further hypothesises that baseline social network/activity will be associated with change in pain outcomes over 18 months follow-up.

6.3.6 Statistical analyses

There are several aspects that determine the selection of statistical analysis methods. These are the research questions (or study hypothesis), study design, and the type of data present (Gonzalez-Chica *et al*., 2015). In experimental studies, such as a randomised controlled trial, to determine whether participants in an intervention group who were administered a treatment had a better outcome (as expected or hypothesised) than a control group who did not receive the treatment (Muller *et al*., 2009), tests of difference would be the preferred choice of statistical tests (Schneider *et al*., 2010; Gonzalez-Chica *et al*., 2015). This is important for a cause and effect study (if exposure to a specific treatment causes an outcome to occur in an intervention group as opposed to a control group). However, in an observational study, if the aim is to determine the relationship between an exposure and outcome such as the present study which hypothesises that social networks is associated with pain outcomes in older adults, tests of association is the preferred choice (Schneider *et a*l., 2010; Gonzalez-Chica *et al*., 2015).

Since the present study was conducted in its natural setting (without any intervention and purely observational), and was a secondary analysis on an existing dataset, experimental manipulation to create control groups (participants without social networks) was not possible. In addition, a participant's social network is a pre-existing status and cannot be experimentally assigned. Therefore, the analytic approach was the adoption of tests of association and not tests of difference.

Correlation Design: As outlined in the Methodology chapter, when a true or quasi-experimental design is not feasible for a study design, then correlational (such as observational, non-experimental, cross-sectional) study designs are an alternative. The present study aimed to examine the strength and direction of the relationship between the independent and dependent variables. Correlation coefficients measure the strength of association, with values ranging between –1 and +1. Stronger associations are indicated by coefficients approaching 1 or -1. Coefficients of ±.10 were interpreted as low correlations, ±.30 as moderate correlations, and ±.50 as high correlations (Cohen, 1988). This approach has an advantage in that it can accommodate a large number of variables. However, since no experimental manipulation is done to the variables at the design or execution stage of the study, correlation analysis cannot conclude the relationship examined among its variables to be causational. However, significant associations can still be used to support potential causal relationships.

In the present scenario and with categorical variables in the data set, Pearson's chi-squared tests of association were conducted for analysis (Gonzalez-Chica *et al*., 2015). Furthermore, since the hypothesis was also to investigate the independent association of exposure (social network) on pain outcome in the presence of a number of covariates, a hierarchical regression analysis was conducted. Regression analysis does this without affecting the clarity and interpretation of results.

6.3.6.1 Introduction to statistical analyses

Univariate, bivariate and multivariate analyses were conducted using IBM SPSS Version 25 (2017). Univariate statistics consisted of descriptive tables for frequencies and percentages describing the measures of interest of the study. Bivariate chi-square tests were conducted to identify the relationship between the social network variable (visual social network, non-visual social network, someone to depend on, social activity) and covariates (socio-demographics, health factors). Potential confounding variables were identified based on the evidence in the literature and/or bivariate statistics. If the literature provided evidence for a relationship between covariates and exposure variables, they were treated as potentially confounding in the current analyses. Also, if the variables had a statistical significant relationship with the exposure variable (as identified using chi-square tests), they were included in the multivariate analysis as covariates. Multivariate analysis was conducted to identify the independent associations between social network variables and pain outcomes, after accounting for any effect of covariates.

6.3.6.2 Descriptive analysis

Descriptive analysis was conducted to achieve the first objective, which was to identify the cohort characteristics and describe them according to social network/activity measures. Frequencies and percentages were calculated for socio-demographic, health, social network/activity and pain factors. Univariate distribution tables have previously been used for describing quantitative data (Peat *et al*. 2004; Docking *et al* 2014). All the measures of interests for the current study are described using distribution tables (as frequencies and percentages) in the results chapter (Chapter 7).

Further analysis to explore any simple relationships between categorical social network variables (visual social network, non-visual social network, someone to depend on, social activity) and covariates (socio-demographics, health factors) were conducted using a chi-square test. Inspection of p-values was used to determine a significant relationship, either significant ($p < .05$) or highly significant ($p < .01$). Results are demonstrated in a bivariate table for association in the results chapter (Chapter 7). This was done in order to allow for identifying any potential confounding variables to account for, when performing regression analyses with independent and outcome variables.

Zero-order correlations between social network/activity and pain variables were conducted to detect for independent associations before conducting multivariate regression analysis. Further on, correlations were conducted for the baseline and 18 months follow-up pain variables (severity and interference). This was done to predict an association between baseline pain outcomes and follow-up pain outcomes.

6.3.6.3 Data screening & assumption tests before conducting regressions

Before conducting the regression analyses, the dataset was explored and tests for assumptions were conducted. The minimum requirement for a sample size for regression and prediction analyses (to look for R^2 and β) was calculated. There were four independent variables, namely non-visual social network, visual social network, someone to depend upon, and social activity. The sample size for the current study was much higher ($n = 749$) than the minimum requirement calculated which was $n = 108$ ($n \geq 104 + p$, where p is total number of predictors).

Next, the data was checked for normal distribution and linearity. Graphical inspection was carried out through histograms and box plots for each variable in the study to inspect for outliers. Normality was checked through P-P and Q-Q plots using the SPSS software (Weisberg, 2013). However, for fairly large sample sizes, non-normality is less of an issue because sampling distribution will be normal regardless of what the sample data looks like (Weisberg, 2013).

Multicollinearity of the independent variables was checked in case they exhibited very high positive correlations with each other. A tolerance value was calculated and if tolerance was greater than 0.2, then multicollinearity was not considered as an issue. However, in cases where the independent variables showed high positive correlations with each other, and tolerance values below 0.2, they were decided to be entered in separate regression models (Weisberg, 2013).

To reduce bias owing to non-normal distribution and the presence of outliers in study variables, data for independent (non-visual and visual social networks) and outcomes (pain severity and pain interference) variables were transformed using log transformation and square root transformation, in spite of the large sample size of the current study (Weisberg, 2013). This was done to correct issues related to a positive skew in the data variables and minimise any potential issue with outliers. Using the transformed data on both independent and dependent variables of the study, some regressions to find out whether social networks/activity predicted pain outcomes were conducted. However, the results from the analyses using the transformed data were equivalent to the analysis of untransformed data. Therefore, the analysis of untransformed data is presented in the results chapter for clarity of interpretation.

6.3.6.4 Regression analysis

Multiple regression was conducted to assess the extent to which the combined set of social network/activity variables were correlated with variance in pain severity, and variance in pain interference, as well as identifying the unique contribution of each social network/activity variable to the prediction of the pain severity and pain interference. The relative importance of each predictor variables on the prediction of pain outcomes was also determined using the standardised beta estimates for each social network/activity variable (Weisberg, 2013).

Hierarchical multiple regressions were used for the analysis in order to allow for the inclusion of multiple independent variables, and to allow for the fixed order of entry of more than two independent variables where required (Field, 2008). This was done in order to test the independent, unique prediction of the outcome variable by each independent variable after accounting for the potential influence of covariates. This method of adjusting during the analysis is advantageous as it allows for both unadjusted (crude) and adjusted results to be expressed. This method becomes useful where the data has been already collected (secondary data analysis) and it is not possible to alter the study design (Field, 2013; Weisberg, 2013). As previously described, socio-demographic and health covariates were taken into account in the hierarchical linear regression analysis to look for an independent prediction of pain outcome by social network measures.

7. RESULTS

7.1 Introduction

This chapter presents the results of the statistical analyses conducted on variables contained in the MBS dataset. Firstly, it describes the characteristics of the study cohort in terms of socio-demographic, health, social network and pain measures using distribution tables. Chi-square tests analysing the relationships between independent variables (social network/activity) and covariates (socio-demographics and health) were conducted to facilitate a decision on which covariates to include in multivariable analysis between independent and outcome variables to adjust for potential confounders. Following this, zero-order correlations were conducted to investigate the simple relationship between independent variables (all measures of social network/activity) and dependent variables (pain outcomes) and to investigate relationships between pain variables at baseline and follow-up. Lastly, the results of the regression are presented, investigating the predictive role of social network/activity on pain outcomes.

7.2 Description of cohort characteristics of the study

The cohort consisted of 60% of participants aged 70-79 years with a slightly higher female proportion (63.2%). The majority of the population were white, and college educated (Table 7.1). This is broadly in line with the demographic findings of a study on the impact of social integration on metabolic functions on a nationally representative sample of US older adult's population, where females (60%) were over represented when compared to males, and 83% of the sample were white and around 46% were high school educated (Yang *et al*., 2013). Table 7.1 demonstrates the socio-demographic, health, social network/activity and pain characteristics of the cohort at baseline.

Table 7. 1 Descriptive statistics for socio-demographic, health, pain and social network measures of the MOBILIZE Boston Study sample

Socio-demographic Variables	n (749)*	%
Age		
70-79	462	61.7
80-89	263	35.1
90-99	24	3.2
Sex		
Male	276	36.8
Female	473	63.2
Race		
White	580	77.5
Black	123	16.4
Others	46	6.1
Years of Education		
Did not finish High school trade and vocational	95	12.6
High school Passed	304	40.5
College Passed	349	46.5

Health Variables	n	% of sample
Body Mass Index (BMI)		
<25	217	28.9
25-29	316	42.1
≥30	198	26.4
Short Physical Performance Battery (SPPB) score		
≤9 poor lower extremity mobility	311	41.5
>9 normal range of mobility	437	58.3
Mobility difficulty		

No difficulty in walking 1/4th of a mile or climbing a flight of stairs	481	64.2
Difficulty in walking 1/4th of a mile or climbing a flight of stairs	267	35.6
Depression		
No	617	82.3
Yes	129	17.2
Cognitive function (MMSE score)		
18-22 mild cognitive impairment	58	7.7
23-30 no cognitive impairment	691	92.3

BPI Pain Severity		
No pain	183	24.4
Very mild pain	182	24.3
Mild pain	195	26.0
Moderate-severe pain	186	24.8
BPI Pain Interference		
No pain interference	285	38.0
Very mild pain interference	132	17.6
Mild pain interference	143	19.0
Moderate-severe pain interference	186	24.8

Non Visual social network		
Score 0	160	21.3
Score 1	589	78.6

Visual Social Network		
Score 0	141	18.8
Score 1	608	81.1

Someone to depend upon		
No	72	9.6
Yes	676	90.2

Social activity		
Low-medium	611	81.5
High	129	17.2

*Total number of values for each variable (*n*) vary due to missing data.

A recent study using a nationally representative sample of home dwelling older adults from the National Social Life, Health, and Aging Project (NSHAP) demonstrated similar cohort characteristics in terms of female representation, white population and years of education (Lindau *et al*., 2018). Analysis on the current study cohort's health data demonstrated that around 42% were overweight and 26.4% were obese, more than 80% had no depression and 92% of the cohort had normal cognitive function. More than half of the participants had no difficulty with lower extremity mobility as recorded by the SPPB score.

The results of the descriptive statistics demonstrated that one quarter of the cohort participants were affected with moderate-severe pain and pain related interference with daily activities. The majority of the participants had a low to medium social activity score. Just under one fifth had a high social activity score. However, 90% of the cohort had someone to depend upon in their social network and approximately 80% of the participants had non-visual and visual social networks.

7.3 Relationship between covariates and independent variables of the study

Chi-square tests were conducted between socio-demographics (e.g., age, sex, education) and social network/activity variables, as well as between health factors (e.g., BMI, depression, mobility difficulty, MMSE and the SPPB score), and social network/activity variables for the current dataset. This identified potential confounders and wherever significant associations were confirmed, these covariates were then introduced in the hierarchical regressions. Results of the chi-square statistics are presented in Table 7. 2.

Table 7. 2 Baseline cohort characteristics according to social network and social activity

	NonVisual Social Network (NV-SN)	
Socio-demographic Variables	0-No (%)	1-Yes (%)
Age*		
70-79	52.5	64.2
80-89	41.9	33.3
90-99	5.6	2.5
Sex		
Male	42.5	35.3
Female	57.5	64.7
Race		
White	76.9	77.7
Black	17.5	16.2
Others	5.6	6.1
Years of Education		
Less than High School, Trade & Vocational	13.2	11.4
Completed High School	36.5	42.3
Completed College	50.3	46.3

	Visual Social Network (V-SN)	
	0-No (%)	1-Yes (%)
Age**		
70-79	49.6	64.5
80-89	45.4	32.7
90-99	5.0	2.8
Sex**		
Male	48.2	34.2

Female	51.8	65.8
Race		
White	81.6	76.6
Black	12.1	17.5
Others	6.4	5.9
Years of Education		
Less than High School, Trade, Vocational	12.1	11.7
Completed High School	35.7	42.3
Completed College	52.1	46.0

	Someone to depend upon (hi407)	
	No (%)	Yes (%)
Age**		
70-79	41.7	63.8
80-89	54.2	33.1
90-99	4.2	3.1
Sex*		
Male	51.4	34.5
Female	48.6	64.6
Race**		
White	84.7	76.8
Black	9.7	17.2
Others	5.6	5.9
Years of Education		
Less than High School, Trade & Vocational	11.1	11.8
Completed High School	37.5	41.5
Completed College	51.4	46.6

Social Activity (SA)		
	Low (%)	High (%)
Age**		
70-79	60.7	69.0
80-89	36.5	25.6
90-99	2.8	5.4
Sex*		
Male	38.8	27.9
Female	61.2	72.1
Race		
White	76.3	83.7
Black	17.3	12.4
Others	6.4	3.9
Years of Education**		
Less than High School, Trade & Vocational	12.5	7.9
Completed High School	40.1	44.1
Completed College	47.4	48.0

Non Visual Social Network (NV-SN)		
Health Variables	0-No (%)	1-Yes (%)
BMI		
<25	31.8	29.1
25-29	39.6	44.2
≥30	28.6	26.7
SPPB Score		

≤9 (Poor Lower Extremity Mobility)	47.5	40.0
>9 (Normal Range of Mobility)	52.5	60.0
Mobility Difficulty***		
0-No (Difficulty in walking 1/4 mile or climbing a flight of stairs)	50.3	68.1
1-Yes (Difficulty in walking 1/4 mile or climbing a flight of stairs)	49.7	31.9
Depression (CESD Score)		
1-No (Depression)	80.4	83.3
2-Yes (Depression)	19.6	16.7
MMSE Score*		
0-Mild cognitive impairment (18-22)	12.5	6.5
1-No Cognitive Impairment (23-30)	87.5	93.5

	Visual Social Network (V-SN)	
	0-No (%)	1-Yes (%)
BMI		
<25	32.8	29.0
25-29	38.0	44.4
≥30	29.2	26.6
SPPB Score*		
≤9 (Poor Lower Extremity Mobility)	51.1	39.4
>9 (Normal Range of Mobility)	48.9	60.6
Mobility Difficulty***		
0-No (Difficulty in walking 1/4 mile or climbing a flight of stairs)	51.4	67.3
1-Yes (Difficulty in walking 1/4 mile or climbing a flight of stairs)	48.6	32.7

Depression (CESD Score)		
1-No (Depression)	82.1	82.8
2-Yes (Depression)	17.9	17.2
MMSE Score		
0-Mild cognitive impairment (18-22)	11.3	6.9
1-No Cognitive Impairment (23-30)	88.7	93.1

	Someone to depend upon (hi407)	
	No (%)	Yes (%)
BMI		
<25	24.3	30.2
25-29	45.7	43.0
≥30	30.0	26.8
SPPB Score*		
≤9 (Poor Lower Extremity Mobility)	55.6	40.1
>9 (Normal Range of Mobility)	44.4	59.9
Mobility Difficulty*		
0-No (Difficulty in walking 1/4 mile or climbing a flight of stairs)	51.4	65.6
1-Yes (Difficulty in walking 1/4 mile or climbing a flight of stairs)	48.6	34.4
Depression (CESD Score)		
1-No (Depression)	86.1	82.3
2-Yes (Depression)	13.9	17.7
MMSE Score		
0-Mild cognitive impairment (18-22)	8.3	7.7
1-No Cognitive Impairment (23-30)	91.7	92.3

	Social Activity (SA)	
	Low (%)	High (%)
BMI		
<25	30.8	26.4
25-29	42.4	45.6
≥30	26.9	28.0
SPPB Score		
≤9 (Poor Lower Extremity Mobility)	39.5	48.1
>9 (Normal Range of Mobility)	60.5	51.9
Mobility Difficulty		
0-No (Difficulty in walking 1/4 mile or climbing a flight of stairs)	64.3	69.0
1-Yes (Difficulty in walking 1/4 mile or climbing a flight of stairs)	35.7	31.0
Depression (CESD Score)		
1-No (Depression)	82.1	87.6
2-Yes (Depression)	17.9	12.4
MMSE Score		
0-Mild cognitive impairment (18-22)	8.4	4.7
1-No Cognitive Impairment (23-30)	91.6	95.3

* $p<0.05$ for χ^2 Test for Trend

** $p<0.01$ for χ^2 Test for Trend

*** $p<0.001$ for χ^2 Test for Trend

Chi Square tests for association demonstrated a statistically significant unique relationship between age and all measures of social networks (Non-Visual, Visual social network, someone to depend upon, and social activity). Older age was significantly associated with a smaller social network and lower social activity. There was a statistically significant relationship between sex and all measures of social network and social activity except with non-visual social networks. Females were significantly more likely to be involved in social activity, and have a greater visual social network compared to males. Years of education were significantly positively related to social activity, with higher educational attainment associated with greater social activity. Mobility difficulty was significantly negatively related to all measures of social network (non-visual, visual social network, and someone to depend upon), demonstrating smaller social networks for those participants with increased mobility difficulty. However, there was, no significant association found between mobility difficulty and social activity ($p = .3$). The trend also reported that the SPPB score for lower extremity mobility was significantly positively related to visual social networks, and someone to depend upon. Sixty percent of participants with a normal range of lower limb mobility on the SPPB scoring, revealed larger social networks and were more likely to report having someone to depend upon.

These results suggest that all socio-demographic variables were related to at least one social network measure and thus these were included as covariates in the regression analyses. Additionally, the health measure of mobility difficulty was significantly related to measures of social network (non-visual, visual, and social activity) and therefore, was included as a covariate in the regression analyses. The SPPB score was not entered in the regression as it was significantly related with only one measure of social network. Since both mobility difficulty and SPPB scores measure lower extremity mobility, only one of them was entered as a covariate in the regression. Furthermore, MMSE was a screening variable presented in the MBS, hence it was not included as a confounder variable in the regression analysis because participants with cognitive impairment (and a score of MMSE under 18 on a scale of 0-30) were excluded from the study (Leveille *et al.*, 2008). The health variables of depression and BMI were not significantly related to all measures of social network and activity. However, the depression variable was included in the regression analyses because of its frequent inclusion in the studies presented in background literature (Peat *et al.*, 2004; Lee *et al.*, 2016; Hung *et al.*, 2017; Musich *et al.*, 2020), which additionally provided evidence of its relationship with both chronic pain and psychosocial aspects of older people in the community.

7.4 Relationship between independent and dependent variables at baseline, & the relationship between pain variables at baseline and follow-up

Bivariate correlations were conducted to determine the strength and direction of relationships between social network/activity variables and pain outcomes both at baseline and follow-up. Results of zero-order correlations are demonstrated in Tables 7.3 a/b.

Table 7.3 a Pearson-correlation statistics for social network, social activity, pain severity and pain interference at baseline

	Variables	1	2	3	4	5
1	Non-Visual SN[1]	-				
2	Visual SN[1]	.693**	-			
3	Social Activity	.196**	.295**	-		
4	BPI[2] Pain Severity	-0.069	-0.026	-0.04	-	
5	BPI[2] Pain Interference	-0.074*	-0.016	-0.126**	.709**	-

**Correlation is significant at the 0.01 level

*Correlation is significant at the 0.05 level

1) Social Networks

2) Brief Pain Inventory

Pearson correlations between social activity and each of the social network measures (non-visual and visual) revealed significant positive relationships. Moreover, these measures, non-visual and visual social network, were highly significantly correlated with each other, as predicted, albeit the correlations between social activity and non-visual and visual social networks were both small (< .3). The correlation between non-visual and visual social networks was moderate to high. The pain measures were also highly significantly positively correlated with each other, with higher levels of reported pain severity associated with greater pain interference.

Measures of non-visual social network and social activity were both significantly negatively correlated with pain interference, although these correlations were very small. Greater non-visual social network and greater scores of social activities were associated with lower levels of pain interference.

Correlations were conducted between baseline and follow-up pain variables (severity and interference) to identify the direction and strength of relationships. Results of zero-order correlations are demonstrated in table 7.3b.

Table 7.3 b Pearson-correlation statistics for pain severity and interference at baseline and 18 months follow-up

	Variables	1	2	3	4
1	BPI[3] Pain Severity (b)[1]	-			
2	BPI[3] Pain Interference (b) [1]	0.709**	-		
3	BPI[3] Pain Severity (18 m)[2]	0.597**	0.499**	-	
4	BPI[3] Pain Interference (18 m)	0.430**	0.564**	0.658**	-

**Correlation is significant at the 0.01 level

1)baseline

2)18 months

3)Brief Pain Inventory

Pearson correlations between pain outcomes severity and interference both at baseline and 18 months follow-up revealed highly significant, moderate positive relationships.

7.5 Independent associations between social network/activity and pain outcomes

The extent to which social networks independently predicted pain outcomes in the presence of other covariates, were calculated using hierarchical regression techniques. Hierarchical linear regressions were conducted for both pain severity and pain interference separately.

The social network and social activity variables were all entered together to predict pain severity and pain interference in separate regressions, one for each pain outcome at baseline, and one for each pain outcome at 18 month follow-up. Since the social network variables (visual and non-visual) were significantly correlated (moderate-high correlation), multicollinearity diagnostics were run in regression analyses by checking the tolerance values. Tests for multicollinearity for the independent variables indicated that a low level of multicollinearity was present (*VIF* = 1.94 for non-visual social networks, 2.08 for visual social network, 1.05 for someone to depend upon and 1.17 for social activity score) when entered together in the same regression model. The tolerance values for each of the independent variables (predictors) in the regression analysis were >0.2. All of the predictor variables had tolerance values between 0.85-0.95 except for non-visual social network, which had a tolerance value of 0.48.

Table 7.4 a Hierarchical regression analysis for non-visual, visual social network, someone to depend upon, and social activity predicting pain severity at baseline

	Variables	B	SEB	β	P
Step 1					
	Non-visual social network	-0.180	0.010	-0.095	0.067
	Visual social network	0.020	0.019	0.057	0.284
	Someone to depend on	0.085	0.190	0.017	0.656
	Social activity score	-0.059	0.049	-0.047	0.229
Step 2					
	Non-visual social network	-0.013	0.009	-0.070	0.159
	Visual social network	0.012	0.018	0.033	0.518
	Someone to depend on	-0.047	0.185	-0.009	0.798
	Social activity score	-0.038	0.048	-0.030	0.428
	Age	-0.175	0.140	-0.046	0.210
	Sex***	0.736	0.161	0.166	0.000
	Race	0.221	0.143	0.058	0.124
	Education***	-0.627	0.119	-0.200	0.000
Step 3					
	Non-visual social network	-0.006	0.009	-0.033	0.491
	Visual social network	0.005	0.018	0.014	0.769
	Someone to depend on	0.023	0.177	0.004	0.898
	Social activity score	0.003	0.046	0.003	0.944
	Age**	-0.371	0.136	-0.097	0.007
	Sex***	0.596	0.155	0.135	0.000
	Race	0.191	0.137	0.050	0.165
	Education***	-0.518	0.115	-0.165	0.000
	Mobility difficulty***	1.287	0.163	0.288	0.000
	Depression*	0.397	0.198	0.070	0.046

Note $R^2=0.007$, $p=0.269$ for step 1; $R^2=0.094$, $p<0.001$ for step 2; $R^2=0.179$, $p<0.001$ for step 3
$\Delta R^2=0.087$, $p<0.001$ for step 2; $\Delta R^2=0.085$, $p<0.001$ for step 3
*$p<0.05$
**$p<0.01$
***$p<0.001$
Where being younger, female sex and having higher education were low risk categories for predicting pain outcomes

The model for pain severity demonstrated that the social network variables explained 0.7% of variance, the addition of socio-demographic variables increased variance explained in pain severity to approximately 8%, and the addition of the health variables of mobility difficulty and depression increased the variance explained in pain severity to 18%.

Demographic variables of age, sex and education were highly significantly associated with pain severity. Older age was associated with an average lower score of -0.371 on the pain severity measure. Male sex was associated with an average score of 0.596 higher on the pain severity scale; and lastly being less educated was associated with an average lower score of -0.518 on the pain severity scale.

Both health factors of mobility difficulty and depression were also significantly associated with pain severity. Standardised beta values indicated that mobility difficulty was the most important contributor to the prediction of pain severity at baseline, with the beta value showing that higher mobility difficult was associated with an average score of 1.287 higher on the pain severity measure. Having a higher level of depression was associated with an average score of 0.397 higher on the pain severity measure

None of the social network or social activity variables independently predicted pain severity. While the association between non-visual social network and pain severity initially approached significance, this was no longer the case once socio-demographic and health variables were added to the model.

Table 7.4 b Hierarchical regression analysis for non-visual, visual social network, someone to depend upon and social activity predicting pain interference at baseline

Variables	B	SEB	β	P

Step 1					
	Non-visual social network*	-0.026	0.011	-0.125	0.015
	Visual social network*	0.043	0.020	0.112	0.034
	Someone to depend on	-0.013	0.205	-0.002	0.951
	Social activity score***	-0.188	0.053	-0.138	0.000
Step 2					
	Non-visual social network*	-0.023	0.010	-0.111	0.027
	Visual social network*	0.042	0.020	0.107	0.040
	Someone to depend on	-0.082	0.203	-0.015	0.685
	Social activity score***	-0.174	0.053	-0.128	0.001
	Age	0.177	0.153	0.042	0.248
	Sex***	0.636	0.177	0.133	0.000
	Race	0.172	0.157	0.042	0.276
	Education***	-0.479	0.130	-0.141	0.000
Step 3					
	Non-visual social network	-0.012	0.009	-0.060	0.190
	Visual social network	0.032	0.018	0.082	0.086
	Someone to depend on	0.013	0.186	0.002	0.944
	Social activity score***	-0.109	0.048	-0.081	0.024
	Age	-0.094	0.144	-0.022	0.514
	Sex**	0.421	0.163	0.088	0.010
	Race	0.137	0.144	0.033	0.341
	Education***	-0.330	0.120	-0.097	0.006
	Mobility difficulty***	1.832	0.171	0.377	0.000
	Depression***	0.804	0.209	0.130	0.000

Note R^2=0.026, p=0.001 for step 1; R^2=0.075, p=0.000 for step 2; R^2=0.232, p=0.000 for step 3
ΔR^2=0.049, p<0.001 for step 2; ΔR^2=0.157, p<0.001 for step 3
*p<0.05
**p<0.01
***p<0.001
where being younger, female sex and having higher education were low risk categories for predicting pain outcomes

A second hierarchical regression was conducted on pain interference scores, using the same predictor variables used in the model for pain severity. Tests for multicollinearity between the independent variables indicated that a low level of multicollinearity was present when entered together in the same regression model. The tolerance values for each of the independent variables (predictors) in the regression analysis were >0.2. All of the predictor variables had tolerance values between 0.85-0.95 except for non-visual social network, which had a tolerance value of 0.47.

The model for pain interference demonstrated that in step one the social network variables explained 2.6% of the variance in pain interference at baseline. The addition of socio-demographic variables increase the explained variance in pain interference to 7.5% and the addition of the health variables of mobility difficulty and depression increased explained variance in pain interference at baseline to 23.2%.

The demographic variable of sex was significantly related to pain interference. Male sex was associated with an average score of 0.421 higher on the pain severity scale.

The results also revealed that social activity independently predicted pain interference after accounting for the socio-demographic and health variables. A one-unit increase in social activity was associated with 0.109 units decrease in pain interference.

Mobility difficulty was once again the most important contributor to the model for the prediction of pain interference at baseline, with the beta value showing that higher mobility difficult was associated with an average score of 1.832 higher on the pain interference measure.

7.6 Prediction of pain outcomes at 18 months by social network/activity variables at baseline

A hierarchical multiple regression analysis was carried out separately for both pain outcomes (severity and interference) at 18-months follow-up. The social network variables were entered in step 1 (non-visual or visual social network, someone to depend upon and social activity, all measured at baseline). In step 2, socio-demographic variables (age, sex, race and education) were added in, and in step 3, the health variables of mobility difficulty and depression variables were entered. Table 7.5 a and 7.5b present the results of the hierarchical regressions showing relationships between baseline social network/activity variables and pain severity at follow-up and pain interference at follow-up respectively.

Table 7.5 a Hierarchical regression analysis for baseline non-visual social network, visual social network, social activity and someone to depend upon predicting pain severity at 18-months follow-up

	Variables	B	SEB	β	P
Step 1					
	Non-visual social network	-0.006	0.010	-0.033	0.567
	Visual social network	0.008	0.020	0.025	0.668
	Someone to depend on	-0.162	0.191	-0.035	0.396
	Social activity score	-0.072	0.053	-0.059	0.173
Step 2					
	Non-visual social network	-0.004	0.010	-0.022	0.697
	Visual social network	0.005	0.019	0.015	0.801
	Someone to depend on	-0.240	0.188	-0.053	0.202
	Social activity score	-0.071	0.052	-0.059	0.172
	Age	0.037	0.150	0.010	0.808
	Sex***	0.793	0.171	0.190	0.000
	Race	0.104	0.152	0.029	0.494
	Education***	-0.433	0.128	-0.143	0.001
Step 3					
	Non-visual social network	0.004	0.009	0.020	0.702
	Visual social network	-0.004	0.018	-0.011	0.839
	Someone to depend on	-0.187	0.179	0.041	0.297
	Social activity score	-0.037	0.050	-0.031	0.453
	Age	-0.174	0.147	-0.047	0.239
	Sex***	0.623	0.164	0.150	0.000
	Race	0.068	0.145	0.019	0.641
	Education**	-0.367	0.122	-0.121	0.003
	Mobility difficulty***	1.315	0.173	0.306	0.000
	Depression	0.312	0.210	0.058	0.139

Note R^2=0.006, p=0.512 for step 1; R^2=0.074, p=0.000 for step 2; R^2=0.168, p=0.000 for step 3

ΔR^2=0.068, p<0.001 for step 2; ΔR^2=0.094, p<0.001 for step 3

* p<0.05

**p<0.01

***p<0.001

where being younger, female sex and having higher education were low risk categories for predicting pain outcomes

The regression model revealed that social network/activity variables entered in step one explained 0.6% of the variance in pain severity at 18 months. The addition of socio-demographic variables in step two increased the explained variance in pain severity at 18 months by an additional 6.8%, and in step three the addition of mobility difficulty and depression increased the explained variance in pain severity at 18 months by a further 9.4%, with the overall model including all predictor variables accounting for 16.8% of variance in pain severity at 18 months.

Tests for multicollinearity for the independent variables indicated that a low level of multicollinearity was present when entered together in the same regression model. The tolerance values for each of the independent variables (predictors) in the regression analysis were >0.2. All of the predictor variables had a tolerance values between 0.85-0.95 except for non-visual social network, which had a tolerance value of 0.48.

Demographic variables of sex and education demonstrated significant relationships with pain severity at follow-up. Female sex was associated with an average score of 0.623 higher on the pain severity scale at follow-up. Having a higher level of education was associated with an average lower score of -0.367 on the pain severity scale at follow-up.

The health variable of mobility difficulty demonstrated significant relationships with pain severity at follow-up, with the beta value showing that higher mobility difficulty was associated with an average score of 1.315 higher on the pain interference measure.

The results of the model including social network variables revealed that baseline non-visual social, visual social networks, someone to depend upon, and social activity variables were not significantly associated with pain severity outcome at follow-up.

Table 7.5 b Hierarchical regression analysis for baseline non-visual social network, visual social network, social activity and someone to depend upon predicting pain interference at 18-months follow-up

	Variables	B	SEB	β	P
Step 1					
	Non-visual social network	-0.010	0.011	-0.050	0.386
	Visual social network	0.013	0.021	0.035	0.551
	Someone to depend on	-0.017	0.206	-0.003	0.935
	Social activity score**	-0.154	0.057	-0.117	0.007
Step 2					
	Non-visual social network	-0.009	0.011	-0.045	0.431

	Visual social network	0.013	0.021	0.037	0.534
	Someone to depend on	-0.004	0.207	-0.001	0.986
	Social activity score*	-0.144	0.057	-0.109	0.012
	Age*	0.336	0.166	0.084	0.043
	Sex	0.271	0.188	0.060	0.150
	Race	0.040	0.168	0.010	0.813
	Education**	-0.398	0.141	-0.121	0.005
Step 3					
	Non-visual social network	0.001	0.010	0.004	0.942
	Visual social network	0.003	0.020	0.008	0.890
	Someone to depend on	0.048	0.193	0.010	0.804
	Social activity score	-0.095	0.054	-1.763	0.078
	Age	0.101	0.159	0.025	0.527
	Sex	0.039	0.177	0.009	0.826
	Race	0.012	0.157	0.003	0.937
	Education*	-0.329	0.132	-0.100	0.013
	Mobility difficulty***	1.589	0.187	0.342	0.000
	Depression**	0.716	0.227	0.123	0.002

Note R^2=0.015, p=0.068 for step 1; R^2=0.044, p=0.002 for step 2; R^2=0.176, p=0.000 for step 3

ΔR^2=0.029, $p<0.01$ for step 2; ΔR^2=0.132, $p<0.001$ for step 3

* $p<0.05$

** $p<0.01$

***$p<0.001$

where being younger, female sex and having higher education were low risk categories for predicting pain outcomes

The regression model for prediction of pain interference at 18 months by social network/activity variables at baseline showed that social network/activity variables entered in step one explained 1.5% of the variance. The addition of socio-demographic variables in step two increased the variance explained in pain interference at 18 months by 2.9%, and the addition of the health variable of mobility difficulty and depression scores in step three increased the explained variance in pain interference at 18 months by 13.2%. The overall model including all predictor variables accounted for 17.6% of variance in pain interference at 18 months follow up.

Tests for multicollinearity for the independent variables indicated that a low level of multicollinearity was present when entered together in the same regression model. The tolerance values for each of the independent variables (predictors) in the regression analysis were >0.2. All of the predictor variables had their tolerance values between 0.85-0.95 except for non-visual social network, which had its tolerance value of 0.48.

The demographic variable of education was a significant predictor of pain interference at 18 months follow-up. Higher education was associated with an average lower score on -0.329 on the pain interference scale at follow-up.

The health variables of mobility difficulty and depression scores demonstrated significant relationships with pain interference at 18 months follow up. Mobility difficulty was the most important predictor for pain interference at follow-up, demonstrating that one unit increase in mobility difficulty led to 1.589 units increase in pain interference at follow-up. Similarly one unit increase in depression would cause 0.716-degree increase in pain interference at follow-up.

Although the predictor social activity variable showed significant associations with pain interference without controlling for other covariates in step one, it was no longer a significant predictor of pain interference at 18 months follow up when all other covariates were added into the model.

7.7 Prediction of changes in pain outcomes between baseline and 18 months by social network/activity variables at baseline

Table 7.6 a Hierarchical regression analysis for baseline non-visual social network, visual social network, social activity and someone to depend upon predicting change in pain severity from baseline to 18-months follow-up

	Variables	B	SEB	β	P
Step 1					
	Non-visual social network	0.008	0.009	0.052	0.369
	Visual social network	-0.005	0.018	-0.017	0.778
	Someone to depend on	-0.177	0.174	-0.043	0.310
	Social activity score	-0.039	0.048	-0.036	0.413
Step 2					
	Non-visual social network	0.008	0.009	0.049	0.394
	Visual social network	-0.003	0.018	-0.010	0.870
	Someone to depend on	-0.013	0.176	-0.031	0.467
	Social activity score	-0.051	0.049	-0.046	0.302
	Age	0.232	0.141	0.069	0.101
	Sex	0.060	0.160	0.016	0.707
	Race	-0.211	0.143	-0.065	0.140
	Education	0.005	0.120	0.002	0.966

Step 3					
	Non-visual social network	0.009	0.009	0.053	0.358
	Visual social network	-0.004	0.018	-0.241	0.810
	Someone to depend on	-0.112	0.177	-0.027	0.528
	Social activity score	-0.052	0.049	-0.047	0.291
	Age	0.192	0.146	0.057	0.188
	Sex	0.068	0.162	0.018	0.676
	Race	-0.229	0.143	-0.070	0.110
	Education	0.023	0.121	0.008	0.850
	Mobility difficulty	0.140	0.171	0.036	0.413
	Depression	-0.246	0.208	-0.051	0.236

Note R^2=0.005, p=0.614 for step 1; R^2=0.014, p=0.260 for step 2; R^2=0.017, p=0.402 for step 3
ΔR^2=0.009, p>0.05 for step 2; ΔR^2=0.003, p>0.05 for step 3
* p<0.05
** p<0.01
***p<0.001
where being younger, female sex and having higher education were considered low risk categories for predicting change in pain outcomes from baseline to follow-up

The regression model for prediction of change in pain severity between baseline and 18 months follow up by social network/activity, socio-demographic and health variables at baseline showed that none of the models significantly accounted for a variance in change of pain severity between baseline and at 18 months follow-up.

None of the demographic or health variables were significantly associated with change in pain severity from baseline to 18 months follow-up, and none of the predictor variables showed any significant associations with change in pain severity from baseline to 18 months follow-up.

Table 7.6 b Hierarchical regression analysis for baseline non-visual social network, visual social network, social activity and someone to depend upon predicting change in pain interference from baseline to 18-months follow-up

	Variables	B	SEB	β	P
Step 1					
	Non-visual social network	-0.009	0.010	-0.048	0.409
	Visual social network	0.007	0.020	0.020	0.738
	Someone to depend on	-0.025	0.194	-0.005	0.898
	Social activity score	-0.004	0.054	-0.003	0.937
Step 2					
	Non-visual social network	-0.009	0.010	-0.048	0.405

	Visual social network	0.006	0.020	0.017	0.773
	Someone to depend on	-0.136	0.196	-0.029	0.487
	Social activity score	-0.013	0.054	-0.010	0.815
	Age	-0.205	0.157	-0.055	0.193
	Sex**	0.529	0.179	0.125	0.003
	Race	0.204	0.159	0.056	0.200
	Education	0.109	0.134	0.035	0.416
Step 3					
	Non-visual social network	-0.007	0.010	-0.040	0.490
	Visual social network	0.004	0.020	0.013	0.833
	Someone to depend on	-0.129	0.197	-0.028	0.511
	Social activity score	-0.005	0.055	-0.004	0.925
	Age	-0.240	0.162	-0.064	0.139
	Sex**	0.493	0.181	0.117	0.006
	Race	0.201	0.160	0.055	0.209
	Education	0.119	0.135	0.039	0.378
	Mobility difficulty	0.241	0.190	0.055	0.207
	Depression	0.120	0.232	0.022	0.605

Note R^2=0.001, p=0.934 for step 1; R^2=0.023, p=0.013 for step 2; R^2=0.027, p=0.351 for step 3

ΔR^2=0.022, p<0.05 for step 2; ΔR^2=0.004, p>0.05 for step 3

*$p<0.05$

**$p<0.01$

***$p<0.001$

where being younger, female sex and having higher education were considered low risk categories for predicting change in pain outcomes from baseline to follow-up

The regression model for prediction of change in pain interference between baseline and 18 months follow up by social network/activity variables at baseline showed that none of the models significantly accounted for variance in change of pain interference between baseline and 18 month follow-up.

Looking at the coefficients table, the only predictor variable significantly associated with change in pain severity between baseline and 18 months follow-up was sex. Being female was associated with an average score of 0.493 higher on the pain difference scores between baseline and follow-up. None of the social network or health variables were significant predictors of change in pain severity between baseline and 18 months follow-up.

8. DISCUSSION

8.1 Overview

This chapter aims to firstly summarise the study results and then discuss in detail the result findings in relation to the study objectives. The second part of the chapter will discuss the strengths and limitations of the study. Lastly, this chapter will highlight the advancements in knowledge, contributions made and future implications of this study.

8.2 Summary of the study results

This study was conducted to investigate whether social networks and social activities play a protective role in chronic pain outcomes in community dwelling older adult populations. The results (chapter seven) from the statistical analyses of the MBS dataset explored the chronic pain epidemiology in this population. Prevalence of pain of MBS participants was reported as 75.6%, similar to the studies presented in the background literature (Thomas *et al*., 2004; Carmaciu *et al*., 2007; Rottenberg *et al*., 2015). 62% of MBS participants had some pain interference with daily activities. However, moderate-severe pain severity and moderate-severe pain interference with daily living for the MBS participants were reported as approximately 25% for both. Studies included in the literature review demonstrated similar figures across similar age groups to that of the MBS participants, approximately 35% for pain experience (Peat *et al*., 2004), 29.5% for pain prevalence (Hung *et al*., 2017), and 29% for back pain prevalence (Musich *et al*., 2019).

The cohort characteristics of the secondary analysis study population had a higher representation of females compared to males that were predominantly white and educated to college level. These demographic characteristics are broadly comparable to studies that used a nationally representative dataset of home dwelling US older adults (Yang *et al*., 2013; Lindau *et al*., 2018). The studies included in the literature review where also predominantly females (Weinberger *et al*., 1990; Weismann *et al*., 2014; Leung *et al*., 2015; Hung *et al*., 2017; Musich *et al*., 19; Mallon *et al*., 2021), with a higher representation of Caucasians (Peat *et al*., 2004; Hung *et al*., 2017; Musich *et al*., 19).

Chi-square tests of the data revealed evidence to support the study hypotheses that there is a relationship between covariates and the social network and activity variable, with older age associated with smaller social networks/activity, and that female sex and more years of education were associated with larger social networks/activity. The older age of the MBS participants was associated with a smaller number of social networks and lower scores of social activities. Being female influenced social networks positively, and further education was an indicator of better social networks and higher scores of social activities. Lastly, the health variable that gave the most positive pain outcomes was the higher mobility difficulty score.

The regression findings for the MBS analyses at baseline and at 18-months follow up are discussed in detail below (subheading 8.3). In summary, the findings provide some evidence for the hypotheses that specific covariates are associated with positive pain outcomes, and establish that being female, of older age, reporting higher mobility difficulty scores, and having depression were significant predictors for greater pain outcomes in the MBS population.

Finally, the hierarchical regression analysis found evidence that greater scores of social activity independently predicted lower pain interference outcomes at baseline in community dwelling older adults (MBS sample population). However, this association was significant at the 18-months follow up period when only the social network variables were included in the regression model, it was no longer significant (p=0.078) once all covariates were added to the model.

The findings revealed that there was no significant association present between the remaining social network factors (visual and non visual, someone to depend upon) and both pain variables at baseline or 18-months follow-up.

8.3 Study objectives, findings and potential explanations

The first objective of this study was to conduct a literature review that would inform and guide the second objective of conducting a secondary data analysis through statistical analysis of the MBS dataset. The findings from the Literature Review, and the results of the secondary data analyses and their possible explanations in association with evidence from the included studies in the Literature Review are critiqued and appraised in the following sections.

8.3.1 Summary of findings from the literature review

Rationale for the included search terms of the review

This review focussed on the quantitative (physical and structural social networks) along with psychological pathways (social support and social engagements) to define and explore its exposure variable. Loneliness even though discussed in relation to pain in the background literature (chapter two, section 2.4.4) was not included in the search terms of the literature review. The main reason for the exclusion was that this study's focus was on structural/quantitative social network factors predicting pain outcomes and not qualitative social factors such as loneliness. Loneliness is '*a discrepancy between an individual's preferred and actual social relations',* that leads to distressing negative feelings of social isolation even when one is among family and friends (Peplau and Perlman, 1982). Even though loneliness is related to the social aspects of an individual, it is different to factors such as social networks, activities, engagements, isolation, and disconnectedness. This is because loneliness is a subjective measure whereas the others are objective measures of social networks. Loneliness is not merely a condition of being physically isolated or being alone (Kovacs *et al*., 2021).

Secondly, including loneliness in the search would have led to the inclusion of a variable not contained in the MBS dataset; which this study used to conduct its secondary analyses on and therefore it did not warrant its inclusion in a pre-analysis literature review.

Finally, a more critical reason was that the background literature on loneliness and pain (refer to chapter two, 2.4.4), which was an informal review of the literature done prior to the specific literature review on current research question, demonstrated evidence that loneliness follows a different pathway to influencing pain outcomes. Although lack of social interaction and living alone are correlated with loneliness, they are distinct psychological constructs (Russel *et al*., 1980). The literature defines and comprehends loneliness differently to other structural and psychological aspects of social networks (Rico-Uribe *et al*., 2016; Smith *et al*., 2019; Kovacs *et al*., 2021). For example, loneliness is defined as a subjective feeling in contrast to social isolation, which is an objective feeling. Social isolation is a result of a decrease in social network size such as the number of social contacts, whereas loneliness is dissatisfaction with quality or quantity of social contacts.

Loneliness is a psychological embodiment of social isolation (Steptoe *et al.*, 2013; Poscia *et al.*, 2017) and is linked to the perceived quality of the person's relationships (Steptoe *et al.*, 2013). However, literature (Jaremka *et al.*, 2013; Smith *et al.*, 2019; Loeffler and Steptoe, 2021) supports that loneliness and its relationship to pain outcomes when explored, could unravel many areas of concerns that can help in developing interventions for better management of pain, provision of healthcare services, and policy makers to reduce the burden of pain in this population. Loneliness, was a distinct element when compared to quantitative aspects of social network variables, influencing the health of individuals differently (through immune dysregulation following different pathology and physiology as evidenced in Jaremka *et al.*, 2013), therefore not within the remit of this thesis but is nonetheless an important variable in relation to pain and warrants future investigation.

Summary of findings from the review

A comprehensive search of various databases on the EBSCO host search engine was carried out and after initial scanning and applying of the eligibility criteria; nine studies were included in the review. The quality of studies included were overall good (approx. 80% of studies had an overall good quality); with an overall low risk selection and measurement bias (refer to chapter four, figure 4.2). However, overall generalisability of the review was low (refer to chapter four, figure 4.3), and was confined to specific populations (only 30% of the results were locally generalised).

The included studies were a mix of longitudinal, cross-sectional, quantitative and qualitative designs. Even though the review included a variety of study methodologies, there were several that were similar, however, there were differences in their exposure variables (social networks, social activities, social support) for the prediction of pain outcomes, but the majority still concluded a beneficial role of social variables on pain outcomes. Two contradictory findings were in relation to an increased pain interference outcome with an increase in the number of children in male older adults (Peat *et al.*, 2004); and an increase in the levels of perceived social support leading to higher pain intensity scores in multi-morbid older adults (Mallon *et al.*, 2021). A contemplated reasoning suggested that male older adults were at higher risk due to being expected to fulfill demands of their children hence an inverse relationship between number of children and pain (Peat *et al*., 2004). Whereas more than 90% of the cohort in the Mallon *et al.* (2021) study were morbid, married and cohabitating with partners hence at ease of receiving instrumental support for pain, resulting in a linear relationship demonstrating an increase in social support increased pain.

The trend of the studies in this review revealed that most of the work on social networks and pain outcome has only been conducted over the last decade. However, a study by Peat *et al.* (2004) on the UK population was one of the earliest in its field, demonstrating a trend of decreased pain interference with an increased frequency of meeting with friends before adjusting for health covariates. The same sample population and its dataset was utilised for the Richardson *et al*. (2015) study which was a qualitative face to face interview-based study and concluded that involvement in the community and an increase in physical and social activities led to living better with pain and a decrease in pain interference with daily activities. This was the case with older adults without pain and those with severe pain (depicted in cohort characteristics of quantitative data in this sample population).

Another significant association was revealed in the Leung *et al*. (2015) study where increased social networks outside the household predicted lowered pain progression longitudinally. These findings provide evidence that engagement in social activity and meeting and socialising outside the household predicted lowered pain interference. However, other studies in this review that explored the social support exposure variable mostly had non-significant associations with pain outcomes after accounting for health variables such as functional disability, stress and depression.

In conclusion, it was evidenced from the review that although social support did not show pain-reducing effects after controlling for other health covariates, social networks outside the household to an extent played a better protective role for pain. Therefore, this review provided background knowledge for directing the MBS dataset analysis and for corroborating further concrete evidence for the current research, *'if social networks and social activities play a protective role on pain severity and interference outcomes or not'*.

8.3.2 Cohort characteristics of the MBS dataset in relation to the literature

The first objective of the secondary data analysis of the MBS dataset was to describe and explore the dataset being used to answer the study's research question (what is the role of social networks (family and friends), and social activities on pain outcomes (severity and interference with daily activities) in older adults living in the community?). Since the study relies on data already collected by the MBS to establish the research hypotheses, it was deemed appropriate to first explore the data and its cohort characteristics as described in chapter seven (section 7.2). This was done to ensure that the dataset had all the vital information needed for the analyses. This step is typical of studies conducted on epidemiological research (such as Peat *et al*., 2004; Docking *et al.,* 2014; Leung *et al*., 2015; Hung *et al*., 2017; Musich *et al*., 2020; Mallon *et al*., 2021). The MBS cohort that formed the sample population for the current study demonstrated in the descriptive analyses, characteristics that were commensurate with the other epidemiological studies included in the literature review. The characteristics included sample cohorts belonging to age groups between 70-80 years, a greater representation of females (60-65%), and a prevalence of both moderate-severe pain severity and pain interference of around 25-30%. These demographic findings are noteworthy specifically due to the geographical population differences of the studies such as the inclusion of Singaporean older adults (Leung *et al*., 2015) UK older adults (Peat *et al*., 2004) and USA cohorts in the other studies (Hung *et al*., 2017; Musich *et al*., 2019; Mallon *et al*., 2021) and also the current study., The differences in culture, ethnicity and social constructs did not appear to affect chronic pain representation in terms of sex and age group.

It was hypothesised in this study that both socio-demographic (younger age, female sex, more years in education) and health variables (better mobility, absence of depressive symptoms) would have a positive influence on predictor variables and thus in some way impact pain outcomes in older adults. However, the variables that showed significant associations after chi-square statistics with measures of social network/activity were age, sex, education, race, and mobility difficulty.

The findings demonstrated that measures of social network (both non-visual and visual) declined with increasing age. This cohort also saw a decline in the social activity score and someone to depend upon with increasing age. Females had larger social networks, engaged in greater social activity, and were more likely to have someone to depend upon than males. These findings are in agreement with the literature where most of the social ties showed an age related decline especially for females (Peat *et al*., 2004; Leung *et al*., 2015). In another study by Hung *et al*. (2017), both increasing age and female gender were significantly related to family support when predicting pain. This demonstrates that even though socially, culturally and ethnically different, older people in pain behave similarly in terms of keeping social ties and engaging themselves in activities, globally. Females (across all the sample cohorts) were at a higher risk of chronic pain, however, when it came to keeping social ties they had larger social networks than males and better social support.

Mobility functions were better among those with better social networks. The results revealed that more than 65% of the participants who had no difficulty in walking a quarter of a mile or taking a flight of stairs had better non-visual social networks. Around 60% of the participants whom had a normal range of lower extremity movement as shown by their SPPB scoring had better visual social networks and someone to depend-upon. This finding of having larger non-visual and visual social network (size and frequency of visits) being related to better mobility functions has been recognised across the literature as more or less cyclic in nature. To elaborate on this, studies have documented that mobility impairment can cause social isolation and even the other way round where having weaker social network support predicts limited functioning, and reduced opportunities for physical activity (Jokobsson *et al*., 2003; Leung *et al*, 2015; Smith et *al*., 2019). This finding can be reasoned by an argument that people who have weaker or smaller social networks, might receive lesser support in managing their daily life, identifying problems, obtaining help, or even developing good behvaiours such as physical activities and hence can be explained in terms of functional limitations.

8.3.3 Correlational statistics of social network, social activity and pain outcomes at baseline and 18 months follow-up

The next step after exploring the characteristics of the cohort was to see if the data was suitable for carrying out relationship analyses between predictor and outcome variables. Simple correlation statistics were computed separately for each individual predictor variable with individual outcome measures, the results of which have been discussed in chapter seven (section 7.4). The different measures of social network revealed positive significant correlations, with specifically high positive correlations between non-visual and visual social network. They were further tested for multicollinearity in the regression models. This was vital in deciding whether separate hierarchical regression analyses with pain outcomes needed to be conducted for these independent variables. Pain severity and pain interference were the two pain outcomes or dependent variables of this study. The pain outcomes showed significant negative correlations with each of the predictor measures. This demonstrated that higher social network/activity scores were related to lower levels of pain outcomes.

Further on, pain outcomes at baseline and 18 months follow-up revealed highly positive significant relationships. For both pain outcomes, an increase in baseline was related to an increase in follow-up. This corresponds to findings in the literature where pain was demonstrated to be a risk factor for pain progression; those in pain at baseline ended up having moderate-severe pain on follow-up as opposed to those with no pain at baseline ending up having mild pain on follow-up (Jakobsson *et al*., 2003; Docking *et al*., 2011; Leung *et al*., 2015). Stating that the pain onset potentially leads to pain progression over time with age can support this finding.

8.3.4 Identifying independent associations between social network, social activity and pain outcomes after controlling for confounding actions of other covariates at baseline

The next objective was to confirm independent associations between social network/activity and pain outcomes. For this, hierarchical linear regression was conducted, the results of which have been presented and described in chapter seven (section 7.5). This was vital to account for any role played by confounding factors such as socio-demographics and health on the prediction of pain outcomes under the influence of social network/activity. These statistical tests have been conducted by studies included in the literature review, when trying to establish associations between independent and dependent variables by regression. Adjustment for demographics such as age, gender, education, marital status and ethnicity, and accounting for health problems such as depression, ADL/IADL limitations, increased BMI, stress etc. when investigating the role of social network or activity on pain outcomes in older adults avoids bias from potential confounders.

In the current study, after adjusting for socio-demographics (such as age, gender, race, and education) and health covariates (mobility difficulty score, and depression), only the social activity scores independently predicted lowered pain interference with daily activities. This finding was statistically significant in the hierarchical regression analysis. However, the relationship with social activity was non-significant for pain severity outcome. Furthermore, none of the social network variables predicted lowered pain severity or pain interference after accounting for the covariates (both socio-demographics and health). However, the non-visual and visual social network variables (size and frequency of visit), before accounting for health factors (mobility difficulty and depression), demonstrated significant associations with pain interference only.

Comorbidities including functional limitation and depression have been shown in literature, as strong covariates related to social network (or support) and social activities when predicting pain outcomes (Peat *et al*., 2004; Leung *et al*., 2015; Hung *et al*., 2017). Moreover, the literature provides support for functional limitation such as mobility difficulty being associated with social network variables (refer to 8.3.2). To confirm the role of social network support on predicting lowered pain outcomes, older people without pre-existing mobility problems need to be explored; this would generate an unbiased association and endorse the current study findings that having a larger social network (quantitative variables) does not predict lower pain outcomes.

Findings from the literature have also suggested that although functional limitation increases with getting older (Jakobsson *et al*., 2003; Thomas *et al*., 2004) it was more prominent in those older adults suffering from pain. Moreover, this study's findings have demonstrated that social activity was strongly associated with lowered pain interference in daily living in older people. The social activity variable also had a measure of physical activity, shaping a debate for physical activity to be potentially protective against pain. However, to confirm that limiting function was not just an outcome of pain but a predictor for pain interference, studies exploring older adults in pain but with no interference with daily activities might be of interest to future research studies. Along similar lines, the qualitative study by Richardson *et al*. (2015) demonstrated that there was no difference found in levels of physical activity and social involvement between those without pain and those with moderate to severe pain but no interference in activities of daily living. Their findings concluded that the sample was physically active not because of an absence of pain, but because of a common attitude towards being socially and physically active maintaining a flexible attitude and willingness to adapt activities.

Moreover, in this study the pain interference questions were related to difficulties in carrying out everyday activities or pain interfering with their everyday instrumental activities. Keeping this in mind, and separating the action of disability due to other health comorbidities (mobility difficulty score, SPPB score), and accounting for their role, predicting associations between social activity and pain interference with daily living was demonstrated. Better social activity scores independently predicted lesser interference of pain in everyday activities of living in this cohort of older adults.

Having said that, a very consistent and vital finding from the current study analyses was that of having depression. Having depression minimised the protective roles of structural social networks (size and frequency of visits) on pain interference with daily activities. The literature provides evidence that both pain and depression have common predictors; having pain at baseline was an independent predictor for developing depressive symptoms and having depression was associated with developing pain over time (Chou, 2007). Furthermore, a pain-depression relationship was found to be stronger in men than in women; but this pain-depression relationship had no effect on age (Geerlings *et al.*, 2002). Studies from the literature have also elucidated that risk factors for the development of depressed mood in chronic pain individuals were age, sex, and psycho-social factors such as social support (Ferreira *et al.*, 2007; Lopez-Martinez *et al.*, 2008), and self-efficacy (Arnstein *et al.*, 1999).

Hierarchical regression analyses conducted on this study dataset also revealed that being female, having fewer years of education, reporting higher mobility difficulty scores and higher depression scores were significantly associated with greater pain outcomes (both severity and interference) in this cohort. This is in line with the findings of Peat *et al.* (2004); Leung *et al.* (2015); Hung *et al.* (2017); Musich *et al.* (2019). For instance, pain prevalence of the cohort sample in the Leung *et al.* (2015) study was associated with disability, being a smoker, female sex, lower socio-economic status and increased prevalence in lower limbs. The current analysis also demonstrated that advancing age independently predicted a higher pain severity outcome (similar association demonstrated by Leung *et al.*, 2015 for pain progression).

8.3.5 Carrying out regression analysis to understand the influence of baseline social networks/social activity measures on pain outcomes over time

Regression analysis revealed that both baseline social network and social activity were not significantly associated with pain outcomes (both severity or interference with daily living) at 18 months follow-up. Higher scores of baseline social activities (p=0.078) were near significant and associated with lower pain interference outcomes at follow-up, when accounted for baseline socio-demographics and health factors. This result is another potentially important finding and deserves more inspection through future research using different population samples and study designs. If this association was confirmed as significant longitudinally through future studies, it would help establish temporal relationship between social activity and pain interference in older people. However, another variable that warrants explanation and further research in relation to social activity and pain interference was depression because it was in particular the entry of depression in the regression analyses that an association between social activity and pain interference became non-significant (p=0.078). Studies have shown physical disability to be a risk factor for depression in individuals with chronic pain (Williamson and Schulz, 1995; Mcllvane *et al*., 2007). Furthermore, a longitudinal study by Hawker *et al*. (2011) supported the idea that chronic pain results in a series of changes, specifically fatigue and disability, which result in depression. Thus the role of depression necessitates more of explanation in its relation to social activity and chronic pain in older adults.

The results demonstrate that being female, having a higher level of education, increased mobility difficulty, and higher levels of depression were all significantly associated with higher pain severity and higher levels of pain interference with daily activities in this sample population of older adults aged 70 and older. These findings are in line with the conclusions of the Leung *et al*. (2015) study where among other factors, being female and better educated was associated with higher levels of chronic pain in Singaporean older adults. They concluded that living with more people was negatively related to the onset of chronic pain, and that weak social networks outside of the household were significantly associated with chronic pain progression, especially in women.

Furthermore to predict change in pain outcomes over 18 months follow-up from baseline, social networks/activity showed no significant associations with pain outcomes. This could be due to changes in social networks that could have occurred over that time period, such as shrinkage or loss, and weakened networks as a result of ageing (Field and Minkler, 1988; Blixen and Kippes, 1999). However, this could not be confirmed in the current study since the social network variable data was only present for baseline and not follow-up. Therefore, future studies should look into both pain and social network/activity variables concurrently over time given the association between the two was established in this dataset at baseline. Social networks not only provide tangible support in older ages but also help to identify problems that require support and assist in obtaining support (Jakobsson *et al.,* 2003). Ironically, in older adults the immediate social ties of support (spouse, partners) themselves get older and are therefore in need of support, hence making the relationship between structural social networks, perceived support and pain outcomes more complex.

8.3.6.Summay of the regression findings

Results of the regression supported the independent role of higher social activity scores on protection against pain interference with daily living cross-sectionally. Longitudinally, for pain interference this finding was not significant for an association with baseline social activity scores once having depression was accounted for at baseline. Lastly, both social networks and social activity showed no significant associations with a difference in pain outcomes at baseline to 18-months follow-up. However, the absence of information on the social network/activity variable at follow-up generated a limitation; hence it could not confirm the concurrent role of social networks and activity over the passage of time. Future studies should look into both changing structural social networks and social activity scores over time and its role on changes in pain interfering with daily living longitudinally. This warrants an exploration since even at baseline the social network variables both non-visual (size) and visual (frequency of visit) predicted pain interference significantly except for when adjusted for having depression and decreased mobility. Therefore, future study samples can aim to include healthy older people with chronic pain but not suffering from comorbidities such as depressive symptoms or functional impairments and follow them up over time to explore and confirm these associations. Such reproducibility of findings would further strengthen the conclusions.

8.4 Strengths and limitations of the study

This study had two main objectives. The first was to conduct a literature review, and second was to conduct a secondary analysis of the MBS dataset. Therefore, the following section aims to briefly discuss the strengths and limitations of both of the objectives.

8.4.1 Strengths and limitations of the literature review

An important requisite of the review was obtaining confirmation from its initial search that there were no existing reviews on the subject. To achieve this, systematic review databases were searched. This confirmed that a gap in background literature existed and a formal review on the current research question was required. This is a strength because it benefits potential researchers by offering assembled, gathered, analysed and synthesised evidence from the existing literature in one place for further exploration, consideration, comparability and reproducibility of findings across a topic.

Another strength of the review was the comprehensive search across databases with no methodological filters applied to ensure a wide coverage. The detailed reporting of the review following the Centre for Reviews and Dissemination (CRD, 2009) guidelines for selection criteria, PRISMA flow diagram for includes studies, and data systematised extraction and synthesis, generated robust results, as well as increasing its transparency and reproducibility. A risk of bias tool from the COCHRANE handbook was applied to check the quality of included studies. This review ended up with both quantitative and qualitative studies included for synthesis of findings that provided comprehensive evidence related to the research question. The included studies overall, had low selection and information bias (classification and measurement biases for assessing exposure and outcome variables). In addition to that, the review in general was valid for the current study hypotheses, all of which added to the credibility of result findings.

However, the review was not without its limitations. The narrow inclusion criteria for a specific age-range and multi-morbid community of older people posed limitations on the generalisability of the results. This was because the presence of morbidity in the shape of depression, functional limitation, and other chronic diseases (Hung *et al.*, 2017; Musich *et al.*, 2019; Mallon *et al.*, 2021) potentially adds to other pathological pathways for psychological stress that would have led to mediating pathways between social networks and pain. This would have caused bias in the association observed, hence reducing reliability and validity of results. This can further lead to inaccurate generalisability of results to the population at large. Having said that, these findings can still hold true for the population in that age range with chronic conditions such as depression, stress, and anxiety.

The included studies used pre-defined and specific exposure and outcome variables, such strict measurement criteria can cause information bias, for example a specific question to define the type of pain outcome (that is a subjective emotion) can cause under reporting owing to forgetfulness or cognitive impairment prevalent in these ages (Thomas *et al.*, 2004; Hung *et al.*, 2017) or even over reporting of pain owing to increased motivation for participation in the study. This could have led to bias in classifying individuals suffering from pain, influencing result findings. Under reporting would have measured cases as non-cases and over-reporting exactly the opposite; hence generating an incorrect association of findings with the exposure variable. This leads to distortion in the measure of associations such as risk ratio or odds ratio (Rothman and Greenland, 1998).

All the more, older adults in general suffer with comorbidities that lead to dropouts because of morbidity issues or deaths in longitudinal studies causing attrition bias as demonstrated in the review. These would have influenced the results because certain groups of individuals dropped out from the study; therefore the sample under study no more represents the target population, affecting external validity and generalisability of the results. Also while conducting analysis with high attrition, if the missing sample data was replaced with mean of previous non-missing data or with last observed value, it could have resulted in bias and the under estimation of variance (Touloumi *et al.*, 2002). In the case of cross-sectional studies, older people usually fail to participate because of health problems and mainly healthy participants end up in the sample cohort, causing systematic selection bias (healthy sample bias). More than half of the studies included in the review were cross-sectional, and the others were longitudinal, hence they were at risk of producing systematic attrition bias.

Another limitation was that the assessment tools used for the exposure and outcome variables were mostly not standardised or consistent across studies. This can potentially limit comparability and synthesis of results, unless a similar pattern is observed in spite of the differences in how the key variable was measured across the studies for making concrete conclusions. The narrative synthesis was done to assemble the result findings, however, this review could have expanded its credibility and reliability from a statistical data synthesis, using a meta-analysis technique. This would have been possible if all (or at least a good proportion) of the studies had followed a standard criterion for assessment of variables and the reporting of results.

While the review was conducted according to the Centre for Reviews and Dissemination (CRD, 2009) and PRISMA guidelines (Moher *et al.*, 2009), only one person conducted the systematic search of the literature. Typically, more than one reviewer undertakes checks of the search results, as this enhances the reliability of decision-making and is strongly advised when conducting a systematic search and in particular for screening the search results (Denison *et al.*, 2013). As this is a PhD, it was conducted independently by the researcher; but even then, the key words used, search criteria, search results, decision on excluded and included studies etc. all were discussed with the supervisors at every step before coming to an agreement for any decision made. This was done to reduce the chance of any reviewer bias to enhance reliability of review findings (Moher *et al.*, 2009), however the risk of biases and quality appraisal forms were both applied to individual studies by the researcher alone and then discussed with the supervisors. Therefore resting the burden of proof on a single reviewer to prove that every possible attempt has been made to ensure that the review is methodologically sound and that all possible attempts have been made in maintaining an unbiased outcome.

Furthermore, articles published in languages other than English were not included due to a lack of translating resources and time. This could potentially cause language bias in the current review. This is because, commonly the positive results have shown to be published in English language journals and negative results were published in non-English local language papers. This would lead to systematic bias and inclusion of only positive results for reviews focussing only on English language papers (Moher, 1996). However, more recently the bias due to language has been reported to be declining owing to a shift in the publication of studies (findings) in English (Galandi *et al*., 2006).

A grey literature search was not covered in this review, but a hand reference search of included studies was performed. This was because more certainty in the quality of the included studies could be ascertained due to the peer-review process that academic journals provide. Having said that, it should be noted that these limitations did not affect the validity of the review since the search was reliably reported for reproducibility.

If conducted again, the literature review would benefit from more than one independent researcher as that would control for any potential outcome reporting bias. Although the implications of these biases on the conduct and reporting of systematic reviews themselves are unclear, some research has identified that selective outcome reporting may occur also in the context of systematic reviews (Moher *et al*., 2009).

8.4.2 Strengths and limitations of the secondary analysis of the dataset

Even though the MBS dataset has information on a wide breadth of variables, it is not necessarily a fully comprehensive collection of variables of the interest variables of interest for the current study analysis. It was also not primarily collected to meet all types of research needs. Since it was collected for a different purpose, some information on the data required by the current study was unavailable. For example, the information on social network variables lacked depth such as telephone or postal contacts in cases of non-visual social networks, as well as information on the social support the network provided. Such information was provided in the Bassuk *et al*. (1999) study, which also defined the social network variable similarly to the MBS definition. Another variable that was missing was that of social economic status (SES) that provides measure for poverty in the participants of the dataset. Although education was used as a proxy for the social status, it was a poor and only choice. Another limitation of the secondary dataset was the manner in which the upper and lower limits of the BMI variable was defined with no clear mention of reason for it in the MBS data code book, however since it was not included in any of the advanced analyses, it did not pose any threat to result findings in the current analysis.

The results from the analysis of the MBS dataset need to be understood keeping in mind their geographical and cultural difference to other parts of the world. The various strengths and limitations of this study and the MBS dataset are discussed below under separate headings.

8.4.2.1 Study design

One of the major strengths of this study was its longitudinal design. Epidemiological studies investigating associations between social network or support variables and pain outcomes have typically used cross sectional data (Jakobsson *et al*., 2003; Peat *et al*., 2004; Weismann *et al*., 2014; Hung *et al*., 2017). However, collecting data at baseline and follow-up generates temporal relationships between predictor and outcome variables and the direction of disease occurrence over time (Leung *et al*., 2015; Richardson *et al*., 2015; Lee *et al*., 2016). The prospective cohort design of the MBS enabled the investigation of relationships between predictor variables and pain outcomes using both baseline and follow-up data, also aiding in indicating the direction of association.

One potential issue with a large-scale longitudinal study such as the MBS is that it is both costly and time consuming. However, the current study conducted secondary data analyses of the existing MBS meaning it saved considerable time generating new results on the specific topic of protective roles of social network/activity on pain outcomes in older people. But since the current author had no control of data collection, depth of information required for the analysis, and the absence of information on some variables leads to limitations in data analysis (discussed later under subheading 8.4.2.5).

However, there are limitations that arise from a longitudinal design. Follow-up studies especially in older adults lead to dropouts, sample loss due to morbidity, deterioration of functional status over time, consequently ending up with a healthy sample causing systematic biases (Jaremka *et al*., 2012; Weismann *et al.,* 2014; Smith *et al*., 2019; Mallon *et al*., 2021) such as attrition bias, recall bias, and healthy sample bias (discussed later under 8.4.2.3). This was the case in the studies included in the literature review where loss to follow-up occurred in older adults owing to their illnesses or deaths in turn influencing the findings; similar was the case in the MBS where 18-20% of participants were lost to follow-up. Those who continue to remain in a study, and are therefore followed-up, usually differ to those who drop out, resulting in the data on the sample population potentially being different to that of the general population (Lee *et al*., 2016; Mallon *et al*., 2021). This has potential implications for the analysis on the follow-up data regarding generalisability of results (because there is a possibility of attrition, non-response and healthy sample bias arising from dropouts in follow-up, as discussed previously); however when conducting epidemiological studies on this population age group, researchers and authors need to prepare for such losses. Otherwise the sample under investigation and analysis ends up being different to the target population and thus affecting representativeness. This influences the external validity of results.

8.4.2.2 Study sample

Given that many of the associations between social network variables and pain outcomes were not significant after accounting for demographic and health covariates, it is important to know if the analysis was sufficiently powered to be able to detect significant relationships. The sample size required for conducting regressions of study associations depends upon the number of independent or predictor variables and their expected effects (strength of relationships) on the outcome (Schneider *et al*., 2010). If the sample population is very small, only very strong relationships will be demonstrable through statistical testing. Therefore, the sample size can be planned based on expectations regarding the coefficient of determination (r^2) and the regression coefficient (b). Furthermore, according to Schneider *et al.* (2010) at least 20 times as many observations should be made as there are independent variables to be studied (Schneider *et al*., 2010). While the process of data collection on a selected number of the sample population had already been conducted, and thus was not within the control of the secondary analysis researcher, the sample was sufficiently large enough for the current study analysis based on the criteria set out in literature that both number of predictor variables and the effect size account for power estimation and sample size (Bujang *et al.* 2017), and to further support its strength and power of sample size, there have been previous studies already conducted and published in the literature (Leveille *et al*., 2009; Eggermont *et al*., 2014) using the sample of the MBS dataset.

The MBS sample was selected using a door-to-door recruitment strategy that targeted the older adult population (≥70 years) living within a 5-mile radius of the Hebrew Research Centre, using list-assisted probability sampling giving all older people in the target area equal probabilities of selection. However, the staff and nurses conducting the telephone interview, home-visit interview and finally the clinical examination confirmed the final eligibility criteria for inclusion; for which they followed a strict inclusion criterion. In total, 765 participants were included in the MBS study, selected by a single random sampling procedure of older people on the town list (list of selected cities, towns, and other populated places in the United States, ordered alphabetically by state with information on demographics), out of which, 749 older adults aged 70 plus (under 70's were removed) form the sample population for the current study. A comparison of the demographics of persons on the town lists with the US Census 2000 showed that the town lists had a comparable distribution by age and sex in the age group of 70 and above (Leveille *et al.,* 2008). This geographic boundary chosen for population recruitment included a wide variety of neighbourhoods in Boston and the surrounding areas ranging from ethnically and socioeconomically diverse urban communities to suburban regions with predominately white, middle-class residents. Therefore, this sample population and hence the findings associated with it have good external validity and can be generalised to the local population.

8.4.2.3 Bias

Epidemiological studies produce results of associations between predictor variables and outcome. While these results might reflect true effects, it may also occur due to chance or bias. Bias can lead to conclude the existence of a valid statistical association where it does not exist and alternatively may conclude no association where it actually exists. Bias occurs due to systematic errors in the research methodology (Hennekens and Buring, 1987).

Selection bias: occurs when a study population does not represent the target population and those who take part in the study are different to those who do not, affecting the generalisability of the study results. These can be of two types, sampling bias or non-response bias in cohort studies (Delgado-Rodríguez and Llorca, 2004). Sampling bias affects representativeness of a study. However, the MBS study sample was representative of its target population. Its geographic boundary and recruitment process of the town's list-assisted random sampling minimised the risk of sampling bias, as the MBS study targeted community dwelling older adult populations only.

A total of 4319 people aged 70 and older were identified, out of which 3822 were screened for eligibility (88.5%). Others were ineligible primarily owing to speaking a language other than English and residing in a nursing home. There were many with unknown eligibility, for example, refusal to complete screening or did not complete the interview. A total of 749 participants aged 70 years and over were deemed eligible and completed both the baseline home interview and the clinical examination (Leveille *et al.*, 2009). Another 16 participants aged 65 and older were added to this sample, which completed both baseline home interview and clinical examination, owing to the fact that they were spouse/partner of the participants of the study and lived in the same household. Therefore, even though the sampling bias was low, there was a risk of non-response bias, another form of selection bias.

Another very common cause for concern in epidemiological research is when participants who are selected at baseline or those who are followed-up are selectively different to those who have opted out of participation or refused initial participation at baseline, with respect to the constructs under investigation (Delgado-Rodríguez and Llorca, 2004). This kind of bias where participants differ from non-participants was demonstrated in the '*healthy volunteer effect'* where participants were healthier than the general population (Melton *et al.*, 1993). Loss to follow-up can be an issue in prospective cohort studies conducted over the years, as participants can drop out for reasons such as illness, death, moving away or refusing to continue with the study. The MBS had around 18-20% of its participants lost to follow-up. However, considering the age groups and chronic health problems associated with this age group, such losses are inevitable. However, studies focussed on older people with comorbidities have demonstrated much larger dropouts and therefore high risk of attrition bias (Lee *et al.*, 2016; Mallon *et al.*, 2021).

Information bias can also occur in the form of recall bias where participants of the study recall the past experiences (pain onset or occurrence or past exposures) more or less efficiently. This can happen in older people with memory deficit where past experiences such as pain onset can be under reported (Hung *et al.*, 2017). It also occurs when older people affected by depression, other social problems such as loneliness over report their pain (Wolf *et al.*, 2015; Jaremka *et al.*, 2013). Systematic recall bias or social desirability bias occurs when over reporting or under reporting of study outcome measures takes place (Smith *et al.*, 2019). In the current analysis, older people were asked to report their pain severity and interference with daily activities on a scale of 1-10. However, those with a cognitive impairment of 18 or more on the MMSE scale (that tests memory function) were excluded from the analysis. Therefore, reducing the impact of recall bias on the findings of the current study. However, such limitations of under and over reporting are always of concern in studies on older adults. Information bias can also result from classification and measurement issues with the exposure or outcome variable. If exposure/outcome assessment tools follow a strict well defined questionnaire that is not validated on different sample populations, they might not grasp the understanding of an older adult to get the right responses and in-turn generate an accurate measure of exposure or outcome. This would end up causing measurement bias due to the assessment criteria not being able to measure what it intended to measure, meaning weak sensitivity or selectivity.

8.4.2.4 Study measurements

The current study's main predictor variables were social network and activity. They were defined in the MBS using a self-administered questionnaire that included a well-validated measure of social networks (Glass *et al.*, 1997), also including the Physical Activity Scale for the Elderly (Herrmann 1997) and the Short Form-12 (Ware *et al.*, 1996) that along with other questions also measured the limitations in social and physical activities. Using a validated questionnaire by the MBS added to the internal validity of this study, which indicated that the measures established a trust-worthy exposure-outcome relationship.

Internal validity of a study signifies that the assessment tools have measured what they were supposed to accurately, producing reliable and valid result findings. The social network variable was a set of nine questions asked in the health interview questionnaire. These questions further divided the variable into two types, non-visual and visual social networks and someone to depend upon. The social activity score was given based on a set of eight questions where scoring was done on the basis of participation and engagement in those activities. The scoring criteria for social network and activity in this analysis were done based on the coding pattern followed in the Bassuk *et al*. (1999) study. This study, through in-home interviews, conducted a comprehensive assessment of social connections and activities using six indicators: presence of spouse, monthly visual connections with at least three relatives or close friends and yearly nonvisual contact (telephone calls or letters) with at least 10 relatives or close friends, frequent attendance (at least once per month) at religious services, membership in other groups, and regular participation in recreational social activities (Bassuk *et al*., 1999). The MBS dataset had information on visual social networks similar to Bassuk *et al*. (1999) study in terms of how often (weekly, monthly) participant had visual contact with their children, relatives, friends. However, the MBS dataset did not have information on non-visual contacts in terms of how often did the participant have non-visual contact (e.g., through telephone or via mail correspondence) with their children, relatives or friends. Instead, it had information on the number of children, relatives or friends a participant had for its non-visual social network variable only. Therefore, the scoring was improvised accordingly. This could act as a potential limitation to this study since there could have been more detailed information describing the non-visual social network variable as described in the literature by Bassuk *et al*. (1999). This is because family relations move out or even settle in different cities for older adults for reasons related to career, partner etc.; in such cases social ties can be maintained through postal or telephone contacts non-visually. Hence missing out information on these could have affected result findings in both directions by either over-estimating associations or under estimating them. However, considering that the current study is a secondary data analysis of the MBS dataset, which was collected for a different purpose all together, these limitations on depth of information for a variable were inevitable.

The social activity variable was defined by a set of eight questions, but some activities described through these questions might have been more probable than others. For example, for older people, playing pool/golf might have been a much less frequent activity as compared to attending a church/synagogue. Therefore, this can pose a limitation on the utility of this measure. These measurements on non-visual social network and social activity scores could be improved by using a similar criterion to the Bassuk *et al.* (1999) study (well-validated social disengagement index). The current study being a secondary data analysis had no control over the depth of data collection on its variables and could not follow specific criteria to define these measures like those used in the Bassuk *et al*. (1999) study. However, many of the social activity questions (visiting a restaurant with a friend, visiting senior centres, visiting family friends) in the analyses were identical to the Bassuk *et al*. (1999) social disengagement index questions and the intention of the authors to judge the older adult's social activity done with other people and not alone (Bassuk *et al.,* 1999) is fulfilled through these specific questions in the MBS dataset. Therefore, the social activity score is a similar indicator of a dimension of social networks of older adults of the MBS.

For measures of chronic pain, previous studies have mostly employed subjective assessments for pain outcomes, using self-report measures (Jakobsson *et al*., 2003; Peat *et al*., 2004; Lee *et al*., 2016; Weismann *et al*., 2014; Hung *et al*., 2017). This method is commonly used to capture pain occurrence because of the subjective nature of pain. This method also facilitates the capturing of the true individual experience of pain (Melzack and Katz, 2001). The MBS dataset had information for both pain severity and interference. Both these outcome measures, by definition, recorded the participant's interpretation of pain. The Brief Pain Inventory (BPI) scale, which is a multidimensional instrument for pain consisting of subscales is a validated questionnaire for individuals with chronic musculoskeletal conditions (Cleeland 1989; Keller *et al*., 2004), and was used for measuring both severity and interference. This was strength of the current study, in terms of measuring its outcome, since large variations in measurement and classification can create problems while interpreting results or making comparisons, also compromising internal validity of a study (Hein *et al*., 2018). However, using a well-validated questionnaire, which has been used in the past by various studies, confirms good internal validity.

8.4.2.5 Data and study analysis

One of the most important issues that an epidemiological study needs to address is dealing with missing values. This can be dealt with a number of ways such as imputation such as replacing missing values with the mean of the observed values for that variable. However, this can severely distort distribution leading to complications and underestimates of standard deviations, and distorting associations between variables of the study (Little & Rubin, 1989). A direct approach to handle missing data is to exclude them, and SPSS (IBM SPSS Version 25, 2017) excludes this list-wise by default when conducting analyses. The missing values for the MBS dataset used for this study analysis was very minimal (no more than 5% for any given variable), and therefore, this added to its strength.

The data needed to be checked for normality and linearity when conducting regression analyses. The key assumptions when conducting linear regressions are normality, linearity, homogeneity and independence. Most of the potential bias in the results comes in the form of a violation of the assumptions, therefore, it is important to test these assumptions as well as explore the data when conducting statistical analyses (Field, 2016). Linearity is the most important of all, which suggests that the outcome variable is linearly related to any predictor or set of predictors (Field, 2016). Central limit theorem suggests that in a variety of situations (significance tests, confidence intervals, parameter estimates) normality can be assumed regardless of the shape of the data in the case of fairy large samples (Lumley *et al.*, 2002). For the current study, the sample population was fairly large (n=749) and hence some non-normality (even if present) was acceptable. Outliers were checked through graphical representations. Multi-collinearity diagnostics were conducted to check for independence, and separate regression models were conducted in case of high positive correlations and lower tolerance values for the predictor variables. This added to the strength of the data analysis for this study.

This study's dataset had some issues with the presence of outliers and therefore to reduce bias in the results owing to violations of some assumptions, data for these variables were transformed using log and square root transformations to check for skewed data and outliers. Using the transformed variables, regression analyses were conducted for verification, however it did not change the direction or magnitude of results as these results were similar to those of the raw MBS dataset. Therefore, the original dataset for these variables were used to generate results of statistical tests.

Regression analysis was conducted to determine associations, where dependent variables must be continuous and independent variables predicting associations can be continuous, binary or categorical (Schneider *et al.*, 2010). The current study used continuous data for both the dependent variable (pain severity and interference) since the pain was measured on a scale of 1-10, with 1 being least and 10 being the most imaginable pain. The present study had more than one independent variable (non-visual, visual social network, someone to depend upon, social activity score), two of which were highly related to each other (non-visual and visual), causing interdependence. This can cause potential errors in estimating the effect of associations between each of the predictor and outcome variables of the study. However, a hierarchical regression analysis with all predictor variables in one model was initially conducted and included multicollinearity diagnostic tests to reveal tolerance values. This confirmed correlation and interdependence between the two variables in question, and therefore it was decided to conduct a single hierarchical linear regression analysis including all independent variables predicting pain outcomes since collinearity diagnostics revealed that tolerance value was > 0.02 for all the predictor variables when entered in the regression analysis together.

In the hierarchical linear regression, the individual effects of other covariates were established when controlling for the confounding actions on relationships between predictor variables and outcomes. The social activity predictor variable independently predicted the pain interference outcome significantly even after adjusting for the covariates. However, the fact that a predictor variable turned out to be significant says nothing about causality; correlations or associations should not be confused with causations. However, because the 18-month follow-up data analyses also demonstrated social activity to be close to significant in being protective against the pain interference outcome in this population in the hierarchical regression model with all covariates adjusted for, and revealed a significant association when tested with all other covariates but without adjusting for the depression variable, future studies on different sample populations with baseline and longitudinal data on both exposure and outcome variables would be needed to confirm strong concrete associations and temporality.

Detailed criterion to identify causal relationships was given by Austin Bradford-Hill (1965) as explained and cited by Fedak *et al.* (2015). The only criterion which epidemiologists universally agree was the establishing of temporal relationship between predictor and outcome (Fedak *et al.*, 2015). Even though the current analysis and results of the literature review findings have shown to predict lower pain outcomes under the influence of social networks/activity, the sample population, measures used to define the independent and dependent variables in the studies from the literature and the current analysis were different from each other. Hence, causality could not be confirmed and requires further research taking into account all of these points.

The correlational nature of the study's analysis limits the determination of a causal relationship. To confirm causality, a true interventional study would be required which is often not possible in applied research and specifically for this study's hypothesis, it would be hard to totally control for a given period of time, an older adult's social environment and engagement in social activities for evaluating unbiased causal associations.

Another issue in predicting relationships is with confounding variables, which is one that makes a relationship appear stronger than it is or even may make it appear weaker than it actually is. This usually occurs due to a failure in controlling for such effects in the association analysis between exposure and outcome. However, in the current analysis this was addressed since the various covariates were introduced in the hierarchical regressions before confirming independent associations. However, it was only possible to adjust for those variables for which information was available in the MBS dataset from the data collection. There may be some variables for which data was not collected in the MBS. In this study, data on socio-economic status was not available, and education level was the only means to control for social status for this dataset. Owing to the study being on post retirement older adults, there was also no data on financial status or employment to evaluate the socio-economic status of a participant while making associations between social networks and pain outcomes. In the Leung *et al*. (2015) study, they have confirmed lower socio-economic status was associated with higher prevalence of pain in older adults.

The current analysis also did not include the information on covariates such as smoking when making conclusions about social network influenced pain outcomes. Moreover, there have been studies confirming influence of smoking on pain outcomes in older people (Leung *et al*., 2015). Evidence from the Shi *et al.* (2010) study identified smoking as a potentially modifiable risk factor for the incidence of pain in a population aged >50 years. Having said that there is strong evidence that smoking is closely related to social class, with individuals of lower social class significantly more likely to smoke (Cavelaars *et al*., 2000). Pain severity is also affected by pain medications. This was not accounted for when making associations in the current analyses.

Pharmacological treatments taken in the form of painkillers for various other illnesses (anticonvulsants, antidepressants), in the process reducing pain interference with daily activities can alter pain outcomes. These are known as adjuvant drugs and are used for purposes other than analgesic but in the process moderate, alter or attenuate pain outcomes (AGS Panel, 2002). This results in an underestimation of results. However, some medications such as for blood pressure and diabetes in older people can also cause indirect pain episodes by the occurrence of light-headedness and falls. This can as a result cause overestimation of pain outcomes where it does not exist. The current analysis did not account for such variables that could have altered pain outcomes in the MBS participants. Therefore, one must be aware of the possibility of residual confounding when interpreting results from the current study analyses.

8.5 Advancement in knowledge and contributions of the study

Although the role of social networks on health outcomes (e.g., cognitive impairment, depression, quality of life, survival and mortality) has been well researched and documented in the literature (Blixen and Kippes, 1999; Seeman *et al*., 2001; Zunzunegui *et al*., 2004; Giles *et al*., 2005; Koizumi *et al*., 2005; Sampson *et al*., 2009; Stephens *et al*., 2011), its potential role in the protection against pain outcomes in older people is sparsely researched and subsequently not well understood. This is especially the case with older adults living in the community. This study tried to bridge this gap and contribute towards the knowledge base, firstly by conducting a literature review on the topic of social networks, social engagement, social support and pain outcomes. Additionally it used a large nationally representative dataset (the MBS) to answer the study's research questions, *'do larger social networks and higher scores of social activities predict lower pain severity and interference outcomes in community living older people?'*

Another important contribution of this study was employing Berkman *et al.'s* (2000) conceptual framework to generate its hypotheses and define the social network measures used to predict its role on pain outcomes (refer to chapter three). Although the framework on social networks has been used previously by studies on cognitive functions (Zunzunegui *et al*., 2004) and mental health outcomes (Stephens *et al*.,

2011) in older adults, it was the first time that this model formed the basis to explore relationships with chronic pain in older people. The studies included in the literature review had not reported the use of either this framework (Berkman *et al.*, 2000) or any other model (on social network measures to predict chronic pain), when generating their hypothesis and research questions. Subsequently, both the findings from the literature review and the current study established an overall protective role of social networks, social activities and engagement when predicting pain in this population in line with Berkman *et al.'s* (2000) framework. Hence this is the first time, the model has been verified by employing some of its variables and measures of social networks to predict pain interference, However, future investigations and applications of the model would benefit from using all of its variables and putting them to test, this would further enhance its credibility.

8.6 Recommendations for future research

The study's secondary analysis of the MBS dataset could not establish significant associations between the measures of social network (size, frequency of visit, having a confidant) and pain outcomes both cross-sectionally and longitudinally after accounting for health variables (mobility difficulty and depression). These results along with the literature review findings envisage that there was little evidence that the number of family/friends is critical (which was measured in the current study) and protective for pain outcomes (severity or interference); but that quality of social networks (which was not measured in the current study) might be critical and more worthy of research time and resource for pain outcomes.

Qualitative aspects of social networks such as predictor action of loneliness in particular should be explored in future studies on social networks and pain in older adults aged 65 and over. This variable was absent in the current study dataset; hence, the current study did not include it in its research question and could not perform an analysis to generate conclusions on it. However, the background literature demonstrated that loneliness had been explored in relation to pain as an outcome variable but not as a predictor (Smith *et al.*, 2019). In another study loneliness was studied as a predictor variable and common risk factor for pain, fatigue and immune dysregulation in cancer survivor patients (Jaremka *et al.*, 2012). According to Oishi *et al.* (2012), people who felt socially disconnected were able to tolerate less physical pain than those who felt more socially connected, suggesting that feeling unconnected to those around you may increase pain sensitivity. There was another recent study conducted on adults aged 50 years and over by Loeffler and Steptoe, (2021) which showed the bidirectional nature of loneliness and pain and evaluated the contribution of factors such as socioeconomic status, physical inactivity and depression. All these findings provide a rationale for including a measure of loneliness in future studies exploring the role of qualitative social networks and pain outcome in older adults living in the community.

Furthermore, the current study analyses also demonstrated that it was the depression variable that was critical and weakened the protective effects of quantitative social networks for pain interference outcomes at baseline and the diminished the protective effects of social activity for pain interference outcome at 18-months. Hence, future studies should also focus on the relationship between pain, depression and social networks in older adults. The relationship between social networks and depression needs to be explored in this population and in particular how it affects pain outcomes. Associations between depression and pain have been demonstrated in the literature (Chou, 2007; Hawker *et al.*, 2011), additionally depression has been shown to be related to quality of life (Demura and Sato, 2003; Scocco *et al.*, 2006). In a cohort study on Mexican older adults, for those whose quality of life was affected because of depression, specific structural social networks have been shown to be protective (Gallegos-Carrillo *et al.*, 2009). Furthermore, structural social networks have also shown shielding effects for depressive symptoms such as higher levels of social integration was significantly associated with lower odds of depression in a nationally representative Irish population sample of older adults (Santini *et al.*, 2015). Longitudinal studies have shown pain leading to depressed moods and vice-versa (Hawker *et al.*, 2011), but which comes first is still contested, therefore to assess the social networks role on pain outcomes, an analysis on depression free sample population should be conducted.

Moving on, however, the social activity scores for the MBS dataset were protective for pain interference outcomes at baseline (significant statistical finding); and for pain interference at follow-up the association was near significant. Therefore, it can be cautiously reported that social activity independently predicted lowered pain interference with daily activities in cross-sectional design for this dataset.

Moreover, in future studies, the social activity variable could be improved in terms of questions used to define and score it so as to improve its utility by using more common questions that represent the engagements and socialising for a particular sex, culture, ethnicity or even country. For example for an older woman from a Black or Asian ethnic minority, questions asked about their social activities would be different to those of a Caucasian women. The social activity measure in the MBS was not weighted, however, only one question (playing golf) out of eight others in the questionnaire, was considered to be less frequent than others. Having said that, it is unlikely that this limitation would have had a great impact on the results of the analyses as most of the questions (visiting restaurant with a friend, visiting family friends, playing cards, visiting church), asked on social activities were very similar to the Bassuk *et al.* (1999) study and they met the intentions of the author to gage that these social activities of older adults were done together with other people, and not alone.

Since information on the social network and activity variable were not present for the follow-up period, it could not be confirmed whether a change in those networks affected the results of the analyses that predicted change in pain outcomes over time from baseline social networks. This is important because social networks have been shown to deteriorate, get weaker, and shrink (due to loss of partners, deaths of loved ones, and living alone or age related morbidity causing a decrease in physical activities, socialising outside of the household, visiting religious places etc.) over time (Blixen and Kippes, 1999; Jakobsson *et al.*, 2003). Therefore, a study with information on varied social network and activity measures over time would investigate the concurrent role of changing social networks on pain outcomes especially in relation to pain interference outcomes.

Such a prospective study should facilitate the use of validated pain measures commonly used in observational studies for research such as the Geriatric Pain Measure and Brief Pain Inventory as evidenced by background literature (Leveille *et al.*, 2008; Lumley *et al.*, 2011). This would in turn enable a better look into pain aspects such as psychometric measures of pain that are more valid and reliable assessments of pain widely used in pain research. They can also limit the weaknesses that accompany the self-report measure of pain (such as issues related to under-reporting, forgetfulness etc.) otherwise also used and accepted both by researchers and participants in pain research (Lumley *et al.*, 2011; Battle *et al.*, 2013; Hung *et al.*, 2017).

Moreover, reproducing the same results using different researchers and populations increases confidence that the conclusions drawn initially from studies like the current one are both reliable and generalisable. This is important because reproducibility is essentially one thing that an investigator can guarantee about a study when proper data analysis accompanied with apt analytical skills are followed and documented (Peng, 2015; Miyakawa, 2020). A reproducibility crisis arises when many scientific studies cannot be reproduced. A lack of raw data has been documented as a serious possible cause for irreproducibility of research findings (Miyakawa, 2020). Replication is the foundation of scientific research, with consistent findings from independent researchers for or against a hypothesis, whereas reproducibility is defined as the ability to recompute analytical results for a given dataset. It therefore enhances robustness of findings (Peng, 2015).

Using different statistical analysis and methods to come to conclusions about associations would add to the credibility and robustness of the result findings of the current study analysis. A more sophisticated analytical approach of structural equation modeling (Sturgeon *et al.*, 2013) or multilevel modeling (Lee *et al.*, 2016; Mallon *et al.*, 2021) could be adopted in future research, which would enable the observation of both direct and indirect pathways between social network and pain outcomes. Furthermore, a cross-lag model (Demirer *et al.*, 2021) could be used to demonstrate the effect of social networks at baseline on pain outcomes at baseline and 18-months; as well as looking at how pain outcomes at baseline might affect social networks at baseline and 18-months.

None of the social networks or social activity measures played a protective role on pain severity outcome at baseline or 18-month follow up in the MBS cohort. This led to non-significant results and, therefore, warrants an explanation through further research to confirm these non-significant associations. If similar findings are reproduced using different populations and study designs, for the same exposure and outcome variables; it enhances reliability and credibility of results. There is a possibility that in older ages, as a consequence of chronic pain, its impact on daily activities is much more affected than its severity. These networks get more complex owing to social isolation in older ages leading to loneliness and functional limitations and therefore affecting pain interference outcome more commonly than other pain outcomes (Jakobsson *et al*., 2003; Peat *et al*., 2004; Smith *et al*., 2019). However, to confirm this, prospective studies looking at qualitative aspects of social networks of older people over a period of time and affected functional outcomes need to be conducted (as suggested at the start of this section).

Drawing on the social network conceptual framework presented by Berkman *et al.* (2000), associations were established between both upstream (socio-demographic variables such as age, sex, education) and downstream pathways (social activities) with pain interference outcome. Moreover, this model partly proved useful for the current study hypothesis and analysis; however inclusion of other variables in the model such as social influence, social support, and characteristics of social network ties (intimacy, reciprocity, reachability) were not within the scope of the current thesis. Therefore, it would be worthwhile to utilise this model and its variables to predict pain outcomes in future studies.

The findings of this study also stress the need to investigate the role of non-pharmacological pain management; this is because many management strategies to treat chronic pain non-pharmacologically in older people are related to social aspects of older people such as psychological support from family, access to health care and instrumental support (all these factors are a part of social network theory conceptualised by Berkman *et al*., 2000). Although the topic of pain management was not explored in detail in this study, there were some studies on pain epidemiology in the literature, which postulated that, owing to a belief that chronic pain is a normal part of ageing (Moltan and Terril, 2014), its management and treatment has been ignored. In their study on older disabled women Pahor *et al.* (1999) reported an under usage of analgesics for pain; almost half of those who reported severe chronic pain were taking either no analgesic at all or a very small dose. In another study on older adults with osteoarthritis, Sale *et al.* (2006) reported that participants did not keep their pain medication in a pill organiser and were more likely to take them only as needed, regardless of the prescription instructions. This was due to concerns of both physicians and older adults about side effects or adverse reactions lead to its under usage (AGS, 2009; Moltan and Terrill, 2014). Older adults also seem to be more worried about addiction to analgesics than younger people are (Sale *et al*., 2006). Moreover, with increasing age, comes cognitive impairment and social vulnerabilities, making the diagnosis and treatment for pain even more challenging in older adults (Schofield, 2006). It can be argued that even taking medications for pain requires one to remember to take them. Stewart *et al*. (2012) conducted a cross-sectional study (secondary data analyses) on the prevalence of both non-pharmacological strategies (NPS) and pharmacological strategies (PS) to manage pain used by the MBS participants suffering from chronic pain; and also identified characteristics associated with the use of these approaches. They found that the use of NPS was greater than PS; even though around half of the MBS participants reported the use of PS, only about a quarter reported regular use. Therefore, it would be inevitable to conduct further research on non-pharmacological approaches to pain management that can be incorporated into older adult's pain management strategies, because they are more able to utilise such approaches (Stewart *et al*., 2012; Moltan and Terril, 2014). Furthermore, future studies on social networks and its role on pain management could explore such non-pharmacological approaches and its effects on chronic pain of older people. Therefore, such a study would also aim to evaluate the moderating effects of pain management on associations between social networks and pain outcomes.

8.7 Implications of research findings & recommendations for policy

The findings of the review and secondary data analysis both suggest that there are non-significant associations between quantitative social network measures and pain severity and interference when accounting for depression and mobility difficulty. Therefore, future recommendations for research on qualitative measures of social networks (such as measures of loneliness, emotional support, belongingness, social influence etc.) require attention. Thus, is it too soon to advocate policy and practice recommendations until there is a better understanding of the relationship between social networks, pain and other health variables.

However, the social activity score demonstrated a shielding role against pain interference for this dataset, and therefore there is some evidence for a potential implication on current policy. The analysis of the MBS dataset concluded an independent protective role of social activities on pain interference in older adults cross-sectionally. Furthermore, literature supports this finding (Richardson *et al.*, 2015; Leung *et al.*, 2015). Therefore, it might be of worth to incorporate it as a supplement to pain medication in later life to help with overall pain management. However, depression and mobility difficulty were important covariates that influenced the relationship between social activity and pain interference at 18-months follow up and diminished the protective role of social activity to only near statistical significance, hence this needs to be observed mindfully when influencing or piloting policy interventions. Furthermore, if this association between social activity and pain interference in community dwelling older adults could also be substantiated or replicated by additional research, there is scope for justifying social activity interventions.

Arguments for incorporating social activity as part of physical activity for better pain interference outcomes in older adults

There is evidence that physical activity is a health behaviour that accelerates meaningful social relationships. It can serve as an alternative to pharmacological treatments for many chronic health outcomes (Pels and Kleinert, 2016). This gives some indication that older people, if socially engaging in physical activities, can benefit their health, and potentially any pain interference as suggested by the current study results.

Physical activity is any bodily movement produced by contraction of skeletal muscles that results in the usage of a larger amount of energy as compared to resting energy expenditure (Caspersen *et al.*, 1985). Being physically active helps in building trusted relationships based on shared interests when incorporated as interventions in small groups of people (Stevens, 2001; Milligan *et al.*, 2013). It operates by reducing loneliness and stress, and increasing social support (Milligan *et al.*, 2013), demonstrating that it indirectly influences the social networks of older adults. Low quality social relationships and social networks in older adults have been shown to be strongly associated with feeling lonely (Shvedko *et al.*, 2018). Regular physical activity has also been associated with a reduced risk of a range of diseases including dementia, cardiovascular disease, depression, mental health conditions, musculoskeletal conditions. For many health conditions such as type 2 diabetes and lower back pain, physical activity has been stated to be as good or better than treatment with drugs (PHE Guidance, 202).

Physical activity interventions along with reducing loneliness and improving psychological well-being, have also been found to benefit other health outcomes such as reduced pain experience, lowered depression, stress, and anxiety (Shvedko *et al.*, 2018). Furthermore, the current study analysis and findings of the qualitative study by Richardson *et al.* (2015) reinforces social activity to be protective for pain interference. These provide some support for influencing policy and practice on social activity as part of physical activity in controlling for pain interference outcomes in older ages. However, physical activities, when introduced to influence pain outcomes, need to be considered in terms of mobility difficulty's in older people, especially since this was another health variable in current study dataset that confounded associations between social activity and pain interference over 18-months. Furthermore, identifying if depressive symptoms are present in older people when suggesting interventions (social and physical activities) that might benefit pain interference needs consideration.

Physical activity (PA) that includes socialising and engagement with others should be encouraged. Staying active in later life has been demonstrated as a vital part of healthy ageing (Goodman *et al.* 2011; Richardson *et al.*, 2015). Almost two decades ago, the American Geriatric Society on pain (AGS Panel, 2002) supported that physical activities that include social engagements lessen the burden of chronic diseases including pain in older people. Furthermore, observational and interventional studies have demonstrated positive effects of PA for diabetes, hypertension, cancer (esp. breast and colon cancer), osteoporosis, cardiovascular disease, obesity, health related quality of life and depression (Warburton *et al.*, 2006; Vuori *et al.*, 2013; Schaller *et al.,* 2015). While there is strong evidence that regular participation in PA brings numerous health benefits to older adults, and interventions to effectively promote PA are being developed and tested, the characteristics and components of the most effective interventions still remain unclear for the older ages group (Zubala *et al.*, 2017). Evidence suggests that interventions to promote PA among older adults are generally effective but there is uncertainty around the most beneficial intervention components. There are indications that purely cognitive strategies might be less suitable for older adults than motivators more meaningful to them, including social and environmental support, and enjoyment coming from being physically active. A whole system-oriented approach is required that is tailored to meet the needs of older adults and aligned with social, individual and environmental factors (Zubala *et al.*, 2017).

Arguments for policy interventions and more weight to social prescribing

The above arguments provide a practical suggestion for policy makers in health care organisations that social activity provision in the form of physical activity and social engagement within the community should be targeted (Zubala *et al.*, 2017) for non-pharmacological management of pain outcomes in the older population. Interventions to encourage more beneficial types of engagement in physical and social activities as people retire would be helpful for ensuring better health and lowered pain interference with daily activities in later life.

The last few years has shown an emergence of interventions focusing on the social components of care, such as social prescribing, art on prescription, exercise/physical activity on prescription, walking groups and the introduction of health trainers, with some evidence for behaviour change (Jepson *et al.*, 2010; Sanchez *et al.*, 2014; Thomson *et al.*, 2015). Interventions involving psychosocial support help people manage their chronic conditions and prevent more serious health problems developing. There is no standard definition for social prescribing but Carnes *et al.* (2017) describe it as a non-medical referral, or la inking service to help people identify their social needs and develop ‘well-being’ action plans to promote, establish or re-establish integration and support in their communities, with the aim of improving personal wellbeing. Social prescribing enables both physicians and health care professionals to refer people to non-clinical services (such as art and music) to provide all-inclusive care (Clements-Cortes and Yip, 2020). Social prescribing recognises that people’s health is primarily determined through a range of social, economic and environmental factors. This method also called ‘community referral’ seeks to address the needs of people in a holistic way and aims to support individuals to take greater control of their own health (PHE Guidance, 2019).

Healthcare professionals also play an important role in using the NHS Health Check as an opportunity to assess physical activity levels using the general practices physical activity questionnaires (GPPAQ). They can subsequently provide brief advice or behaviour change support. Social prescribing is another important area that GPs and other healthcare professionals should focus on for referral as a supplement to medical solutions (Carnes *et al*., 2017). Through social prescribing, individuals presenting through primary health care can be signposted and connected to local organisations, groups and activities. There are social prescribing schemes that focus on physical activity and those staff with knowledge of the resources available in the local community match individuals to opportunities and support them to engage in activities (PHE Guidance, 2019).

8.8 Summary

Key findings

Social activity scores were protective for pain interference outcome independent of other covariates cross-sectionally. Quantitative social networks did not demonstrate a protective role for both pain outcomes (severity and interference). Depression in older ages overshadows the benefits of firstly social networks on pain outcomes, and secondly diminishes the protective role of social activity on pain interference over time.

Take home messages

Depression in older adults needs to be addressed before planning any interventions to tackle pain problems. Further research on the relationship of depression, social networks and pain outcomes needs attention, exploring both samples with and without depressive symptoms.

Qualitative social network measures such as loneliness have shown to be related to pain outcomes in older people in literature, therefore, this requires profound consideration in areas of research on social networks and pain in this population.

Social activity was found to be protective against pain interference in the short term; hence future research substantiating or replicating these results is warranted. This would then possibly provide scope for including social activity as part of physical activity and influencing policy and practice.

9. CONCLUSIONS

This study has identified the existing evidence available on the role of social networks, both structural and functional, and engagement in social activity for pain outcomes in community dwelling older adults through its literature review. Additionally, secondary data analysis of the prospective MBS dataset was conducted and found that higher social activity scores predict lower pain interference outcomes in this population cross-sectionally but less so longitudinally.

There have been many studies exploring risk factors of chronic pain, and considerable attention has been given to the consequences of the psychological and physical impact of chronic pain in older adults in regard to depression and functional disability. These consequences, such as disability, also pose a risk factor for advance pain severity and interference with daily living in this population; and much of the research focused around pain are on these topics. However, there has been very little research examining the protective factors of chronic pain in community dwelling older adults, and in particular the psychosocial factors. Theoretical concepts such as by Berkman *et al*. (2000) have been developed on the protective role of social networks on chronic health outcomes such as cognitive impairment (Zunzunegui *et al*., 2004) and mental and physical health (Stephens *et al*., 2011); however, the literature review conducted in this study, identified large gaps in what is known about the protective roles of qualitative and quantitative social networks and social activity on chronic pain outcomes in community dwelling older adults. This was in spite of a large amount of literature documented on social network measures and its protective roles on health outcomes other than chronic pain in older people. Therefore, the current study through the application of a conceptual framework (Berkman *et al*., 2000) in generating hypotheses and objectives in relation to chronic pain, established some important associations between community living older people's social networks and social activity on predicting their chronic pain.

This study has identified the population characteristics in regards to pain outcomes in an older adult population, confirming previous findings from the literature that chronic pain is an increasing problem for older people in the community (Jakobsson *et al*., 2003; Thomas *et al*., 2004; Peat *et al*., 2004; Leung *et al*., 2015). It has contributed towards new knowledge by adopting a conceptual framework to define its hypotheses and objectives as opposed to similar studies identified in the literature review, whilst using more refined and complete measures of both social networks and pain outcomes.

This research has demonstrated that social networks in older people is a complex phenomenon as this population is more affected by pain interference in their daily activities. Therefore, there is a possibility these networks might get more complicated in older age leading to more functional limitations and hence social isolation. However, to confirm this, prospective studies looking at social networks of older people over a period of time and measuring their social networks and affected functional outcomes need to be conducted.

This study and the literature both suggest that both structural (non-visual) and functional (visual) components define social networks, and social activity and social support were an added dimension of networks in older adults that need to be studied when predicting health outcomes such as chronic pain in older people. This makes reasonable sense since engagement in activities, such as attending church, visiting a restaurant with a friend or visits to senior centres (some of the activities of the current analyses) and having support (especially emotional) and a sense of belonging to your family and friends, requires networking with people in society; hence could be pathways of being part of a larger social network outside the household (Berkman *et al.*, 2000). These also initiate supportive behaviours (exercise, physical activity), which are demonstrated to be protective against pain, depression and other chronic conditions in older ages.

Many studies in the literature (Zunzunegui *et al.*, 2004; Stephens *et al.*, 2011) have presented these concepts for the role of social networks on health outcomes through cascading pathways transferring wellbeing from macro to micro factors to individual health outcomes. The concepts originally laid down by Berkman *et al.* (2000) helped to structure the analysis of this study and in turn, this study further established these concepts for pain outcomes in older people. The MBS analyses demonstrated that both upstream social variables and network factors and downstream social activity factors played a protective role on pain interference outcomes when acting individually and in conjunction.

This study further confirmed engagement in social activities as an independent predictor for lowering pain interference outcomes. This finding (engagement in social activities) was not significant but was close to a significant association over time (18 months), therefore a temporal relationship with pain could not be established. Nonetheless, engagement activities could offer both emotional and instrumental support through various other social ties, developed through being socially involved, which in turn could contribute towards lowering pain outcomes. However, to make such conclusions, and to establish temporality more studies need to be conducted using different sample populations.

It has been identified that there is a gap in defining and classifying both qualitative and quantitative social network variables and utilising standardised assessment for those that have been used to explore relationships with pain outcomes in older people. There remains a further requirement to develop refined social network tools and sophisticated instruments to measure them in older people for better use in cohort studies. These can then be used to predict chronic pain outcomes.

The analyses conducted in this study also found that risk factors such as female sex, lesser years of education, higher mobility difficulties, and depression independently influenced greater pain severity and pain interference outcomes in this population. These are indications that certain groups of people in society (such as those with lesser years in education) are at increased risk of greater pain outcomes. In particular, females reported higher pain outcomes, and males were found to have more restricted social networks. These are indications of factors associated with pain issues and strategies required to manage it for particular social groups. Both the literature review and the MBS data analyses demonstrated the negative role of depressive symptoms overshadowing the protective role of social networks on pain outcomes.

The social activity score predicted pain outcomes independently over 18 months in the MBS dataset, apart from when the depression variable was entered in to the model. However, once depression had been adjusted for, the association was no longer statistically significant between engagement in activities and pain interference over time. This finding acknowledges the role of the quality of social networks that could have an impact on how depression affects the outcome of interest. This adds to earlier arguments that suggest a better exploration of the loneliness in regards to chronic pain in this population.

In conclusion, pain remains a highly prevalent problem in older age. Risks for pain outcomes in this age group are multi-factorial, and even though social networks did not predict lower pain outcomes, engagement in social activities was found to be protective against pain interference.

9.1 Personal reflections and plans for the future

My journey as a PhD research student has been a steep learning curve and transition from a postgraduate student into an independent researcher. There were challenges along the way, which I was able to face and overcome with the support of my loved ones at home, my colleagues, staff at the university, and my resourceful supervisory team. I had to face unforeseen circumstances along the way; however, it developed me as a researcher and made me able to work more independently. Nevertheless, the supervisors I have had over the years have always been very supportive and their feedback has been constructive and pivotal in shaping me as a researcher. I learnt a lot about academic critical writing in my first and second years along with learning in detail about methodologies and statistics in the second and third years. The final and fourth year was the execution of all that I had learnt and developed over the three years and putting to test my ability as a critical thinker and synthesiser to complete my writing up. After the fourth year, I submitted my completed PhD and sat my final viva. I gave it my best but it did not turn out to be as anticipated and I was required to make amendments after the viva and its outcome. However, being heavily pregnant I could not attend to the needs of corrections and changes in the write up at the time. I therefore went on maternity leave for almost a year and then the Covid19 pandemic happened which changed the world, as we knew it. During these unpredictable times, life was tough and I ended up taking a break from my PhD for two years. Coming back to my studies and then addressing the examiners feedback and comments wasn't easy with a toddler in tow.

There is a lot that can be said about what I have learnt and what I have developed constructively over the period of my PhD years from both my strengths and weaknesses as a researcher early on, and later as an individual who developed perseverance, motivation and patience. A PhD is not only about a degree earned from acquiring knowledge in your area of research but it is a lifelong lesson learnt. Especially in my case it has been a roller-coaster ride where having a set back (losing my first supervisor of three years, to cancer) and then failing my first submission and having to resubmit for the first time in my academic journey, to being a new mom and then encountering a pandemic and everything that came along with it on both a professional and personal front. It became more than just studying, it was the seeking of an individual who can combat a lot of things and multi-task and accomplish her goals regardless.

However, the two most important elements of lessons and reflections acknowledged in terms of learning advice for myself or for any early career researcher in the field would be; firstly it is great to be enthusiastic and confident and plan when you start research but the best results come to competent researchers who are ready to consider and plan in advance for any unforeseen situation, unplanned outcomes, unacceptable circumstances, unimaginable challenges, as all of this is what will develop you as a comprehensive all-round independent researcher. Secondly, that it is always a good idea to explore up-to-date information on the subject of interest and any novel findings, however this must be in conjunction with the historical landmarks and research done early on in the field to learn from areas of limitations and how they were bridged over time to bring advancements in the field.

Following this resubmission, I plan to publish the findings of this work so that this subject area can benefit from the knowledge gained. I also look forward to the future beyond my PhD where I will aspire and work hard to get involved and work on post-doctoral research studies hopefully on chronic pain and the ageing population. So far, I have obtained an assistant fellowship award form UK HEA and, therefore, along with the research aims, I also aim to continue to work in higher education to inspire researchers and students like myself gained from my experience and knowledge. This will help me to keep revisiting areas of new information and new knowledge. My career plan for much later and hopefully in the next ten years is to be a public health research professional. This is because I strongly believe that research is incomplete without its outcomes having an impact on policy and practice.

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11. APPENDICES

11.1 Appendix 1: Data extraction form for literature review

1. General Information

Study ID (author 1 surname and year of publication)	
Title of main publication/paper/report	
Country (region/city)	
Year study started (baseline examination)	
Duration (m/y)	

2. Eligibility

Study characteristic	Review inclusion criteria
Type of study (cross-sectional, cohort, longitudinal, case-control)	
Population (age, type, setting)	
Disease/ condition	
Type of outcome measure	
Decision on inclusion criteria	

Only proceed for included studies

3. Population and setting

Population description	
Source of population	
Method of recruitment of participants	

4. Methods

Aim	
Design	
Sampling technique	
Start date	
End date	

5. Participants

Total number of participants/ sample size	
Age group	
Notes on participants	

6. Exposure

How was exposure assessed	
Exposure name	
Exposure definition	
Time points measured	
Type of exposure measurement	

Exposure assessment tool validated or not	

7. Outcomes

How was outcome measured (physical examination/self-report)	
Outcome name	
Outcome definition	
Time points measured	
Type of outcome measurement (percentage/OR/RR)	
Outcome tool validated or not	

8. Results and findings

Outcome	
Subgroup	
Main findings	
Any other results reported	
Risk factors reported	
Statistical methods used and its appropriateness	

9. Strength and limitation

Strength	

Limitations	
Strategies to overcome limitations	

10. Conclusions

Key conclusions	
Notes	

11.2 Appendix 2: Risk of bias tool for systematic literature reviews

Questions on external/ internal validity	Yes/ No/ Unclear	Reference from text (in the paper)
Was the study's target population a close representation of the national population in relation to relevant variables?		
Was the sampling frame a true or close representation of the target population?		
Was some form of random selection used to select the sample?		
Was the likelihood of nonresponse bias minimal?		
Was an acceptable case definition used in the study?		
Was the study instrument that measured the parameter of interest shown to have validity and reliability?		
Were the limitations of the study reported?		

11.3 Appendix 3: CASP checklist for quality assessment of included studies

A. Are the results of the study valid?

- Did the study address a clearly focused issue?
- Was the cohort recruited in an acceptable way?
- Was the exposure accurately measured?
- Was the outcome accurately measured?
- Have the authors identified all-important confounding factors?

B. What are the results?

- How precise are the results?
- How strong is the association
- Is their any bias in results, which is reported?

C. Can the results be generalised to local population?

- Do the results of the study fit with other evidence?
- What are the implications of the study for practice?