Title

The use of the CR-10 scale to allow self-regulation of isometric exercise intensity in pre-hypertensive and hypertensive participants.

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Conflicts of interest

None declared

Abstract

Purpose: Isometric exercise (IE) has been shown to lower blood pressure (BP). Using equipment with force output displays, intensity is usually regulated at 30% maximal voluntary contraction (MVC); however, the cost of programmable equipment and their requirement for maximal contractions presents limitations. A simple, cost-effective alternative deserves investigation. The purpose of this study was (i) to explore the relationship between %MVC, change in systolic BP (ΔSBP), and perceived exertion (CR-10) and (ii) to assess the validity of self-regulation of intensity during isometric handgrip exercise.

Methods: Fourteen pre-hypertensive and hypertensive adults completed eight, 2-minute isometric handgrip exercises at randomised intensities; participants estimated their perceived exertion at 30-second intervals (Estimation Task). Subsequently, on three separate occasions participants performed four 2-minute contractions at an exertion level that they perceived to be equivalent to CR-10 "Level-6" (Production Task).

Results: There were significant linear relationships between the estimated exertion on the CR-10 scale, and ΔSBP (r=0.784) and %MVC (r=0.845). Level 6 was equivalent to an average ΔSBP of 38mmHg (95% CI; 44mmHg, 32mmHg) and a relative force of 33% MVC (95% CI; 36.2%, 30%). During the production task, %MVC was not significantly different between the estimation task and each production task. In at least the first two repetitions of each production task, ΔSBP was significantly lower than that observed in the estimation task.

Conclusion: These findings show that CR-10 "level-6" is an appropriate method of self-regulating isometric handgrip intensity; its use offers an affordable and accessible alternative for isometric exercise prescription aimed at reducing BP.

Keywords: CR-10 scale, exercise prescription, estimation-production model, isometric exercise, perceived exertion.

Abbreviations:

BP	Blood pressure
ΔSBP	Change in systolic blood pressure
IE	Isometric exercise
MVC	Maximal voluntary contraction
RPE	Rate of perceived exertion

Introduction

The impact of hypertension on mortality rates is a growing concern worldwide (WHO 2013). European and North American guidelines recommend exercise as a non-pharmacological lifestyle modification for the treatment of hypertension (Mancia et al. 2013; Brook et al. 2015). Evidence for the blood pressure (BP) lowering effects of isometric exercise is growing (Börjesson et al. 2016). To date, studies have reported that isometric exercise lowers BP in healthy adults (Wiley et al. 1992; Ray and Carrasco 2000; Howden et al. 2002; Millar et al. 2008; Wiles et al. 2010; Devereux et al. 2011; Badrov et al. 2013a; Devereux and Wiles 2015; Gill et al. 2015), hypertensive (non-medicated and medicated) and pre-hypertensive adults (Wiley et al. 1992; Taylor et al. 2003; McGowan et al. 2006; Peters et al. 2006; McGowan et al. 2007b; Baross et al. 2012; Baross et al. 2013; Millar et al. 2013; Badrov et al. 2013b). Due to the mounting evidence, The American Heart Association is the first organisation to recommend isometric exercise as an effective strategy to treat and prevent hypertension (Brook et al. 2015).

Studies that have been carried out in pre-hypertensive and hypertensive participants have mostly used isometric handgrip exercises. Training protocols include 4x2minute contractions (performed unilaterally or by alternating hands), repeated 3 times per week for 8-10 weeks (Millar et al. 2014). To date, the majority of isometric training programmes have prescribed a percentage of maximal voluntary contraction (%MVC) to regulate the exercise intensity (Taylor et al. 2003; McGowan et al. 2007b; Stiller-Moldovan et al. 2012; Millar et al. 2013; Badrov et al. 2013b; Ash et al. 2016). This method requires a device (e.g. handgrip, hand dynamometer) that displays the magnitude of force exerted which then allows the exercise participant to visualise force output (on a computer screen or the device itself) and maintain it at a pre-set target. Calculating %MVC also requires the performance of 2-3 short maximal efforts to firstly establish MVC. The most common target handgrip exercise intensity is 30% MVC. Specifically, this training intensity has been effective at lowering resting systolic BP (SBP) by 6-19mmHg and resting diastolic BP (DBP) by 3-15mmHg in pre-hypertensives and hypertensive adults (Wiley et al. 1992; Taylor et al. 2003; McGowan et al. 2007a; Millar et al. 2007; Badrov et al. 2013b).

However, regulating isometric exercise by using %MVC presents a number of limitations. Firstly, specialised programmable handgrip devices or dynamometers, designed to calculate %MVC prior to the beginning of each exercise session, are required. These are somewhat expensive and some dynamometers can only be used in the laboratory. Secondly, the calculation of %MVC requires 2-3 all-out maximal efforts, which might present a limitation in some groups of participants, especially in those with frailty. Some older adults are limited in maximal gripping, due to the prevalence of varying

degrees of arthritic pain in the hand (Arthritis Research UK 2017). If this type of exercise is to benefit older people with hypertension (or who are at risk of hypertension) then it must be simple to use, affordable, home-based and ideally it must avoid maximal effort. There has been little exploration of alternative ways to regulate IE intensity.

In other types of exercise modalities (e.g. running, cycling, rowing) studies provide support for the use of the rate of perceived exertion (RPE) chart as an exercise prescription tool. During cardiorespiratory exercise, perceived exertion charts (Borg 1973) have been shown to correlate strongly with physiological markers of intensity such as heart rate and oxygen consumption (Borg and Kaijser, 2006; Scherr et al. 2013; Ueda and Kurokawa, 1995). Using an estimation-production model researchers have also shown that participants can replicate specific markers of intensity (heart rate, oxygen consumption, power output) by producing a given level of perceived exertion (Eston et al. 1987; Marriott and Lamb 1996; Green et al. 2002; Goosey-Tolfrey et al. 2010; Paulson et al. 2013; Soriano-Maldonado et al. 2013).

The CR-10 scale is a perceived exertion chart and was developed by Gunnar Borg with the intention of using verbal expressions that are easy to understand (Borg 1982). With regards to IE, a strong linear relationship has been previously determined between the Borg CR-10 scale and %MVC during 5-second contractions (Pincivero et al. 2000). However, its relationship with %MVC during longer isometric contractions is unknown. In addition, the use of perceived exertion and its relationship with cardiovascular responses during IE remains unexplored. Recent findings show that an individual's systolic BP change (ΔSBP) in response to a single 2-minute isometric handgrip task at 30% MVC is related to the magnitude of training-induced BP reductions in hypertensive individuals (Badrov et al. 2013b). Within this sample (n=12) findings showed that those with a small ΔSBP (~10mmHg) responded less positively to isometric training whilst individuals with a larger ΔSBP (up to 50mmHg) responded most positively (Badrov et al. 2013b). Considering the wide range of SBP changes observed during IE and its potential impact on training adaptations, further examination of the ΔSBP and its relationship to the CR-10 scale and %MVC requires investigation.

The purpose of this research was to firstly determine the validity of regulating IE intensity using perceived exertion. Specifically, an estimation task examined the relationship between the Borg CR-10 scale and both %MVC and ΔSBP. Based on the initial findings, the research determined whether individuals could reproduce (production task) %MVC and its corresponding ΔSBP using an imposed numerical value from the CR-10 scale. Three production trials were carried out to assess whether practice trials are necessary to improve an individuals' accuracy at producing a specific exercise intensity.

Methodology

Fourteen (9 females, 5 males) pre-hypertensive and stage 1 hypertensive adults (SBP; 141±6.6mmHg, DBP; 84±6.4mmHg) with a mean age of 64.4±5.7 years, body mass of 73.3±16kg and stature of 166±12.4cm participated in the study. Participants were classified according to the European Society of Hypertension criteria (Mancia et al. 2013); pre-hypertensive participants had a resting seated SBP of 130-139mmHg and/or 85-90mmHg, hypertensive participants had a resting SBP of 140-159mmHg and/or 90-99mmHg. Five participants were taking anti-hypertensive medication which included diuretics (n=1), ACE inhibitors (n=2), calcium channel blockers (n=1), alpha blockers (n=1). Those with SBP >160mmHg or <130mmHg, a history of cardiovascular events or diabetes were excluded from participating. Ethical approval was granted by the local research ethics committee and written informed consent was obtained from all individual participants included in the study.

Research design

Participants attended the laboratory on five occasions. Each visit was separated by a minimum of 48 hours and maximum of 7 days. Pre-visit conditions were standardised with each participant avoiding food (2 hours), caffeine (12 hours) and alcohol (24 hours) prior to each laboratory visit.

Familiarisation session

Stature and mass were measured on arrival at the laboratory (Seca, Bonn, Germany). This was followed by completion of a Physical Activity Readiness Questionnaire; PAR-Q+ (Jamnik et al. 2011) Participants were then instructed to sit comfortably in a chair (back supported, legs uncrossed, feet flat on the floor) whilst BP was measured during 10 minutes of quiet rest. BP was measured using a non-invasive Finometer MIDI device (Finometer MIDI, Finapres Medical Systems, Amsterdam, Netherlands) which was attached to the middle phalanx of the third digit on the dominant hand. An average of the final two minutes of recording was used for the baseline BP (day-of BP). Throughout all testing procedures, acute changes in SBP were calculated based on day-of BP. This device has been validated against intra-brachial BP measurements and whilst its use in measuring absolute BP values is inappropriate, tracking changes or trends in BP is supported (Imholz et al. 1991; Bos et al. 1992).

Following the resting period, participants were instructed on how to use an isometric handgrip dynamometer (AD instruments LTD, Sydney, Australia). Whilst retaining their comfortable seated position, participants held the handgrip device in their non-dominant hand whilst holding their arm adducted with 90 degrees of flexion at the elbow joint. A brief isometric hand-grip warm-up was then completed using three, 15 second contractions at approximately 50%, 75% and 90% of maximal effort.

The handgrip dynamometer was connected to an 8-channel chart recorder (Powerlab 26T, AD instruments LTD, Sydney, Australia) and interfaced with a computer analysis system (LabChart Pro 7 software, AD instruments LTD, Sydney, Australia).

On completion of the warm-up, the CR-10 was introduced. The following explanation was given to participants to read;

"During the exercise bout, I want you to pay close attention to how hard you feel the exercise is. The feeling should reflect your total amount of fatigue, combining all sensations and feelings of physical stress, effort and fatigue. Do not concern yourself with any one factor such as arm pain, shortness of breath or exercise intensity but try to concentrate on your total, over all feeling of exertion. Try not to underestimate or overestimate your feelings of exertion; be as accurate as you can" (Modified from Faulkner and Eston, 2007).

An anchoring procedure was then used to assist the participant in putting into context the sensations of exercise intensity (Nobel and Robertson, 1996). Resuming their comfortable seating position and holding the dynamometer loosely, participants were asked to *"think about your feelings of exertion and assign a rating of 0 to those feelings".* Following this, participants were asked to maximally grip the handgrip device for 3-5 seconds (breathing evenly throughout). Prior to the contraction, participants were asked to *"think about the feelings of exertion at the end of the contraction and to assign a rating of 10 to those feelings".* The maximal exertion task was repeated 2 more times with a 1-minute rest in between. The maximal value attained was recorded as the participant's MVC.

To complete familiarisation, three handgrip intensities ranging from 15% to 35% were calculated and randomly assigned. With the assistance of a force output visual display participants carried out 2-minute contractions at the appropriate intensity with 4-minute rests in between each contraction. During each 2-minute repetition participants were requested to provide a rating from the CR-10 scale every 30 seconds. Acute BP changes were recorded throughout.

Estimation task

The baseline BP measurement, warm-up and anchoring procedures all followed the same procedures as the familiarisation session. Following three MVCs (1-minute rest between each effort) participants undertook eight, 2-minute contractions at randomised intensities ranging from 10% to 40% MVC (5% increments). A force output visual display screen was used to assist participants in maintaining the correct intensity. Each contraction was separated by a 4-minute rest period. Participants were requested to provide a rating from CR-10 scale every 30 seconds. Blood pressure was measured

throughout using the finometer midi device (Finometer MIDI, Finapres Medical Systems, Amsterdam, Netherlands).

Production task

All eight contraction intensities provided 32 ratings from the CR-10 scale (every 30 seconds during each 2-minute contraction). A linear regression was carried out on the CR-10 ratings and the calculated average of the corresponding %MVC and ΔSBP. The linear regression revealed that CR-10 "Level-6" aligned with an average relative force value of 33% MVC (95% CI; 36.2%, 30%) and an average ΔSBP of 38mmHg (95% CI; 44mmHg, 32mmHg). Level 6 was subsequently used in production tasks on three occasions (trials 1-3), each separated by 7 days.

Day-of BP, warm-up and anchoring procedures were all repeated before each production task. Participants were then asked to carry out four, 2-minute isometric handgrip contractions whilst maintaining the CR-10 rating at "level-6". A 4-minute rest was provided between each contraction. The participant was blinded to the force output display but was informed of the time elapsed throughout.

Statistical analysis

Data was analysed using the statistics package for social sciences (IBM, version 23, Armonk, NY). Analyses was carried out specifically for the *estimation task*, *estimation task v's production task (trials 1-3), and production task (trials 1-3)*.

Estimation task

The relationships between CR-10 and %MVC and CR-10 and ΔSBP were subjected to linear regression.

Estimation task v's production task (trials 1-3)

Average values for ΔSBP and %MVC were calculated across each 2-minute contraction (repetitions 1-4) carried out during the production trials. For each production trial, a 1-way ANOVA was used to detect differences between CR-10 "level-6" estimation and CR-10 "level-6" production; post hoc analysis was performed using a Bonferroni test for pairwise comparisons. The alpha level was set at 0.05. Effect sizes (ESs) were also calculated (Cohen's d), and values of 0.1, 0.3 and 0.5 were considered small, moderate, and large effects, respectively (Field 2009).

Production task (trials 1-3)

For each production trial, average force was calculated for four separate time segments of the 2-minute isometric contraction (0-30s, 30-60s, 60-90s, and 90-120s); each time segment was averaged across all four contractions. Pearson correlations assessed the relationship between segments of time and force. A repeated measures ANOVA with Bonferroni adjustments was used to detect between trial differences at each time segment. The alpha level was set at 0.05.

Results

Estimation task

Significant linear relationships (Fig. 1) were observed between the CR-10 scale and the calculated average of the corresponding %MVC (r=0.845) and ΔSBP (r=0.784). Level 6 on the CR-10 scale aligned with an average ΔSBP of 38mmHg (95% CI; 44mmHg, 32mmHg) and an average relative force value of 33% MVC (95% CI; 36.2%, 30%). Therefore, the common prescription of 30% MVC was deemed to be closest to "Level 6" and was adopted for use in the isometric production trials.

Estimation task vs production task (trials 1-3)

One-way ANOVA with Bonferroni adjustment showed that the relative force was non-significantly different (p>0.05) between the estimation task and all repetitions in all three trials of the production task (Fig. 2).

In production trial 1, the ΔSBP was significantly lower than the estimation task during repetition 1 (p=0.000, ES=2.00), 2 (p=0.000, ES=1.82) and 3 (p=0.000, ES=1.35). In production trial 2, the change in SBP was significantly lower than the estimation task during repetition 1 (p=0.000, ES=2.13), 2 (p=0.000, ES=1.64) and 3 (p=0.003, ES=1.31). In production trial 3, the change in SBP was significantly lower than estimation task during repetition 1 (p=0.000, ES=1.65) and repetition 2 (p=0.025, ES=1.05) (Fig 2).

Production task (trials 1-3)

Figure 3 shows that %MVC decreased in a moderately linear fashion (relative to segments of time) in trial 1 (r=0.583), trial 2 (r=0.594) and trial 3 (r=0.645). Between trial differences were detected with a significant interaction for time*day. Percent MVC during the first time segment (0-30s) was significantly greater in trial 3 as compared with trial 1 (p=0.021, ES=0.354).

Discussion

The aims of this study were two-fold. Firstly, the study aimed to establish whether a relationship exists between the CR-10 scale and either %MVC or ΔSBP (Estimation Task). Secondly, the study aimed to assess whether, when using an imposed number on the CR-10 scale, participants were able to produce an exercise intensity that equated to a specific %MVC and which elicited a sizeable ΔSBP. Results from the estimation task indicated that a strong linear relationship exists between the CR-10 scale and both %MVC and ΔSBP (Fig. 1). Specifically, the estimation task revealed that "level- 6" on the CR-10 scale aligned with an average %MVC of 33% (95% CI; 36.2%, 30%) and an average ΔSBP of 38mmHg (95% CI; 44mmHg, 32mmHg). The most common isometric exercise prescription, aimed at lowering BP in previous studies, has been set at 30% MVC (Wiley et al. 1992; Taylor et al. 2003; Millar et al. 2007; Badrov et al. 2013b). Based on the positive reductions in BP observed after these training interventions prescribed at 30% MVC, the findings from the estimation task indicated that the CR-10 "level-6" would most closely approximate the exercise intensity that has been used previously. Therefore, it was concluded that this CR-10 level would be the most appropriate level for isometric exercise prescription within the production task (trials 1-3).

The production task trials revealed that it was possible for participants to adequately self-regulate their exercise intensity using "level-6" on the CR-10 scale (Fig. 2). Further, familiarisation trials are not necessary to improve the accuracy of participants' ability to produce the intensity that was observed during the estimation task (average 33% MVC) at CR-10 "level 6". This is the first study to demonstrate the ability of individuals to self-regulate isometric exercise effort (force) by using a rating of perceived exertion scale. The ability to self-regulate isometric exercise intensity, without the need to establish maximal voluntary contraction (MVC), would potentially offer greater access to this type of exercise for some groups (especially those with frailty or arthritic pain of the hand). Indeed, using this self-regulation method would allow participants to perform isometric exercise in a self-regulated (controlled) way, whilst using a myriad of different types of resistance (other than squeezing with the hand). Any 'immovable object' around the home or workplace could be utilised. Of course, further validation studies would be required before this is possible.

In contrast to the current study, inaccuracies in reproducing a given exercise intensity in an exercise-related production task have been found (Marriott and Lamb 1996). As compared with an estimation task, cyclists overproduced their power at an RPE level of 11 ("light"), 13 ("somewhat hard") and 15 ("hard"). However, power output at an RPE of 17 ("very hard") was produced successfully (Marriott and Lamb, 1996) . Within the current study, CR-10 "level 6" indicated an effort level somewhere

between "hard" and "very hard". Although it is difficult to compare aerobic and isometric exercise, it could be suggested that it is easier to self-regulate exercise intensity when it is above what is described on the rating of perceived exertion scale as "hard".

Despite the reproducibility of %MVC using an imposed CR-10 "level 6", its corresponding physiological parameter (ΔSBP) determined during the estimation task was under-produced across each production task; this was particularly evident in the first 2 repetitions of all production trials (Fig. 2). These findings suggest that although ΔSBP is significantly related to increasing CR-10 levels during an estimation task, this physiological response is not readily produced during a 2-minute isometric handgrip task despite the accuracy of %MVC reproduction.

There are two potential explanations for this difficulty in achieving this physiological change during the production protocol. Firstly, the calculation of the ΔSBP during estimation and production tasks were inherently different. Whilst the ΔSBP during the production task was calculated for each 2-minute period of exercise, the estimation task value represents the ΔSBP averaged across a number of periods of exercise. The latter is therefore representative of a cumulative hemodynamic effect. The cumulative effect of previous periods of isometric exercise is evident in repetition number 4 in all production trials, where ΔSBP was not different to the estimation task value (Fig. 2). Although previous research has shown that SBP increases over the course of single periods of isometric exercise lasting varying lengths of time (Lind and McNicol 1967; Smolander et al. 1998; Greaney et al. 2015), the current research is the first to show that despite a 4-minute rest between repetitions, the hemodynamic response accumulates and is still evident during consecutive periods of isometric exercise. This response is presumably related to progressive muscle fatigue and accumulation of metabolic by-products. In contrast to repetition number 4, the SBP response during repetition number 1 was not influenced by an accumulation of prior exercise and revealed a wide range of individual SBP responses (6-35mmHg). This wide range is in agreement with findings from Badrov et al. (2013). To reiterate their findings; lower responses (~10mmHg) to a single isometric handgrip task predicted smaller BP benefits following 8 weeks of isometric handgrip training. The findings of the current study are important because it clarifies the existence of inter-individual differences in response to a single isometric exercise contraction (repetition 1, production trials 1, 2 and 3). This finding supports the notion that there is potential for isometric exercise to benefit some individuals more than others (Badrov et al., 2013), however, more research is warranted. The interplay of a number of factors may be responsible for the individual variations. Differences in central command output, sensitivity of mechano- and metabo-reflexes or baroreflex function, are likely candidates for varied responses amongst different individuals (Smith 2010). In addition, hypertension status (pre-hypertension and

stage 1) and anti-hypertensive medications (which have been shown to dampen levels of reactivity; Benschop et al. 1994) may have contributed to this inter-individual variation.

Secondly, the estimation task was regulated by a consistent force output (%MVC) whilst the production task was entirely self-regulated (CR-10 "level-6"). In contrast to a consistent force output, this study showed that self-regulation of intensity using the CR-10 scale resulted in a time-dependent decrease in force (Fig. 3). This may have acted to minimise increases in central command, thereby, reducing cardiovascular drift (i.e. ΔSBP) during the 2-minute period of isometric exercise (Williamson 2010). Isometric exercise regulated by %MVC is thought to gradually increase levels of central command in response to fatigue, resulting in a continual upward drift in cardiovascular parameters (Wiles et al. 2010). This drift was likely to be more evident in the estimation task as opposed to the production task. However, considering the high pressor response experienced by some hypertensive individuals in response to isometric exercise (Delaney et al. 2010; Badrov et al. 2013b) the use of the CR-10 scale should be effective in minimising this upward drift in cardiovascular parameters.

It is interesting to note that ΔSBP was achieved by rep 3 in trial 3 as compared with rep 4 in trail 1 and 2. This response was most likely a result of a learning effect and altered strategies in regulating isometric intensity. Figure 3 shows that the %MVC in the first time segment (0-30s) of trial 3 was significantly greater than trial 1; this may have stimulated the greater pressor response seen during production trial 3. However, considering that repetition 1 is most predictive of BP reductions (Badrov et al. 2013), the authors believe that this difference between trials is not vitally important.

In conclusion, the current research shows that the use of CR-10 "level-6" is a novel and cost-effective way of self-regulating consistent and appropriate hand-grip isometric exercise intensity in older pre-hypertensive and hypertensive participants. Findings showed that following familiarisation, individuals can reproduce appropriate isometric intensities without the need for practice trials.

Limitations and recommendations for future studies

It should be noted that the current findings are representative of a small population and are limited to pre-hypertensive and hypertensive males and females. Further analysis of the use of the CR-10 scale to self-regulate isometric exercise intensity is required in larger populations where sub-group analysis including sex, age, initial resting blood pressure and medication status can be carried out.

It remains to be established whether the use of the CR-10 "level-6" can be used during an isometric training programme to successfully induce a reduction in BP in this population. If successful, future studies might be able to utilise home-based isometric exercises that offer versatility that may not even

require equipment. Finally, future studies will need to determine whether a brief and self-instructed anchoring procedure would be sufficient to familiarise participants with the CR-10 "level-6". This would obviate the necessity for an exercise professional to train participants in relation to the use of the scale. This would further enhance the simplicity and accessibility of a self-regulated isometric exercise method.

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