VELOCITY CHANGE ESTIMATION BY SUBJECTIVE MEASURES OVER A WIDE-LOAD SPECTRUM IN SQUAT AND BENCH PRESS

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ABSTRACT

This study compared whether the perception of effort measured on a repetition-by-repetition basis during continuous sets to failure are different between squat (SQ) and bench press (BP). After determining the 1RM value in both SQ and BP, eighteen participants (28.2 ± 5 years, 50% females) performed seven sets to failure per exercise, separated by 24-h to 48-h, alternating SQ and BP, using the following relative load-ranges 30<40%; 40<50%, 50<60%, 60%<70%, 70<80%, 80<90% and >90%. The mean accelerative velocity (MAV) and Rating of Perceived Exertion (RPE) using the OMNI-RES (0-10) scale were measured for every repetition of each set. The ability of the OMNI-RES (0-10) scale to identify velocity changes during continuous sets to volitional failure and to distinguish loading zones divided into 10% slots, from 30 to 100% of 1RM was confirmed for both SQ and BP. The RPE values measured at (i) the first repetition; (ii) the repetition where MAV peaks; (ii) the repetition where MAV drops by ≤10% compared the maximum and (iv) the last repetition, showed no differences ($p>0.05$, $d<0.2$) between exercises. In conclusion, the same RPE scores can be applied to both exercises, for either estimating the relative load and monitoring changes in MAV during continuous sets to failure.

Keywords: OMNI-RES (0-10) scale, muscular failure, perceptual response, RPE, resistance training.

INTRODUCTION

Velocity-based training is a method that uses movement velocity to inform or enhance training practice (34). This approach establishes velocity thresholds considering the gradual decrease in the exercise velocity occurring as the sets progress over the workout (36). Thus, the ability to exercise with a given velocity range, e.g. ≥90%, or ≥80% with respect to the maximum movement velocity determined at the beginning of the workout, in each exercise and loading range, dictates the interruption of the set (16). Larger velocity losses (e.g. >10%) have been associated with higher metabolic stress and greater hypertrophic related outcomes (31). Conversely, smaller losses (e.g. <10%), maintaining ≥90% of the maximal velocity will enhance mechanical power output, by selectively activating type II motor units and avoiding the accumulation of protons resulting from a progressive predominance of the glycolytic system if the set continues (7,36). Accordingly, the design of resistance training using dynamic exercises should consider two main variables: (i) loading zones, estimated as percentage one-repetition maximum (%1RM), and (ii) movement velocity, where the degree of velocity loss experienced as the set or the entire workout progress influences the training effect (28,31). Therefore, maintaining the appropriate intensity while exercising with a given load at the desired velocity is a meaningful factor impacting training outcomes, e.g. increase mechanical power output, or muscular endurance (29). Even though several velocity control devices, such as accelerometers, velocity transducers (3) and camera-based systems (20) have been validated and are currently used by coaches and researchers, this technology might not be available or is still difficult to apply for all exercises. Consequently, alternative methods are necessary to objectively estimate performance progression or changes in exercise velocity.

The perceptual response emerges as a useful tool to monitor intensity during self-paced physical activity (1). Research has reported promising results on using Rating of Perceived Exertion (RPE) scales to estimate loading zones (11) and monitor changes in movement velocity (4) during resistance exercises. Chapman and colleagues conducted two similar studies examining whether changes in movement velocity during the squat (4) and the bench press (5) exercises can be predicted by the subjective response. Results demonstrated that the RPE evaluated by the OMNI-RES (0-10) scale can be used to indicate fluctuations in movement velocity during continuous sets to failure. When data from both aforementioned studies were compared, the initial RPE, associated with specific relative load range (%1RM), seems to be similar between squat and bench press. Nonetheless, the RPE associated with a 10% loss in the movement velocity showed similar scores only for the moderate to heavy loads (≥ 60%). Furthermore, although some studies reported similar perceptual responses from exercises involving upper vs. lower body musculature (13), others have observed opposite results. Mayo et al. reported higher RPE in back squat compared to bench press after performing workouts including either to-failure or not-to-failure sets (22). Thus, it is important to further understand the influence of the exercise on the elicited perceived exertion during the performance of resistance training. Additionally, although the perceptual response is assumed to be similar between males and females either during single joint (30) or upper and lower body multi-joint exercises (24,25), few studies have analyzed the RPE response during continuous sets of resistance exercises in mixed balanced (males and females) samples (8,9). Particularly, the study of Emanuel et al. (2020), examined the perceptual response on repetitions by repetition basis in both squat and bench press but testing only two loading ranges (70 and 83% of 1RM).

To the best of our knowledge no study so far has systematically described the pattern of perceptual response during sets to failure over a wide load range (30 to 100% 1RM) comparing upper and lower body exercises in a mixed balanced sample of men and women. The aim of the present study, therefore, was to compare whether the values of perceived effort measured after each singular repetition during continuous sets to failure are different between upper- vs. lower-body resistance exercises performed over a wide load range (~30 to >90% 1 RM) in a mixed balanced population (50% females). Additionally, we explored the ability of the RPE (i) to differentiates instances where the movement velocity peaks, drops ≥10% from the maximum or reaches muscular failure and (ii) to discriminate between relative-load ranges divided in 10% incremental slots (~30 up to 100% 1RM). We hypothesized that the RPE values used to identify changes in the movement velocity and to differentiate loading zones are similar between upper- and lower-body exercises.

METHODS

Experimental Approach to the Problem

The study followed a within-participant design. After determining the individuals' 1RM values, in both bench press (BP) and squat (SQ), the participants were evaluated on 14 occasions (7 per exercise) until achieving muscular failure with the following 1RM percentage ranges in random order: 30 to <40%, 40 to <50%, 50 to <60%, 60% to <70%, 70 to <80%, 80 to <90% and >90%. The mean accelerative velocity (MAV) and the OMNI-RES (0-10) scale value, as a measure of the RPE, were obtained for all the repetitions of each set. The study compared the RPE scores collected at four critical points (first repetition, when MAV peaks, drops ≥10% from the maximum or reaches muscular failure) during continuous sets using a wide range of relative loads in two different exercises (BP and SQ).

Subjects

Eighteen recreationally resistance-trained participants, nine males [mean ± standard deviation (SD): 28.7 ± 5.2 years, body mass 84.4 ± 13.0 kg, and height 179 ± 5.0 cm] and nine females [27.7 ± 4.1 years, body mass 64.1 ± 13.7 kg, and height 169 ±7 cm] took part in this study. To be eligible, participants were healthy and free of injury in the last three months prior to the intervention. They were furthermore required to train regularly between 2 to 3 times per week, using routines including free-weight squat and bench press for a minimum of two years before the beginning of the study. Additionally, participants had to have experience in performing sets to task failure. However, to maintain a homogenous sample, recreationally trained individuals looking for general fitness benefits (e.g. gaining muscle mass, reducing body fat or physical wellness) with no regular participation in sports competitions (e.g. powerlifting, weightlifting, athletic jumping or throwing), were considered eligible for the present study.

Only individuals non ingesting ergogenic aids or any type of nutritional supplements affecting muscular performance for 12 weeks or longer prior to the start of the study were recruited. Participants were instructed not to change their nutritional habits, and if relevant modifications were reported (i.e. becoming vegetarian, restricting calories, taking nutritional supplements, etc.) participants' data were excluded from the analysis.

The sample size was determined based on RPE scores reported in previous studies using similar designs, exercises and population (4,5). Assuming an α-error of 0.05, coefficient of 0.5, nonsphericity correction of 1, considering an effect size $f = 1.6$, for a repeated measure within factors, a minimum sample size of n=6 was estimated to achieve ≥80% statistical power.

All experimental procedures were conducted in accordance with the Declaration of Helsinki. Each participant read and signed an informed consent on the first day. This study was approved by the University Research Ethics Committee.

Procedures

Before the beginning of the study assessments, all the participants underwent two familiarization sessions. During these sessions, the OMNI-RES (0-10) scale procedures were explained to the participants in order to appropriately evaluate the perception of effort of the whole body (32,33) after each repetition of the training exercises including SQ and BP. The OMNI-RES (0-10) scale includes both verbal and mode-specific pictorial descriptors distributed along a comparatively narrow response range of 0 to 10 (Figure S1, supplementary material). These characteristics make this chosen scale a useful tool to estimate effort during resistance workouts (26).

*Exercise*s

Both, BP and SQ were performed using free weights. For SQ, the participants performed the exercise within a squat rack starting from standing, feet parallel and shoulder width apart with toes pointing slightly outward. The bar was either centered across the shoulders just below the spinous process of the C7 vertebra (high-bar position) (37). Participants were instructed to squat down with a controlled velocity until their posterior thigh was positioned parallel to the floor. After a minimum pause (less than 1 s), participants performed the concentric squatting phase with the maximal possible velocity. For BP, the participants started lying down on a bench with their elbows fully extended to begin lowering the bar towards the chest using a controlled velocity. After a minimum pause (less than 1 s), participants performed the concentric phase with the maximal possible velocity. One qualified instructor (a certified strength and conditioning coach, CSCS or UKSCA) monitored the appropriate range of motion for both SQ and BP.

Assessments

1RM and Repetitions to Failure tests

The 1RM value for both the BP and parallel SQ was assessed according to the methodology described by McGuigan (23). To avoid any specific muscle group interaction, the order of testing for BP and SQ was randomized. Briefly, participants performed a specific warm-up set of 4 repetitions at ~50% of their predicted 1RM followed by another set of 3 repetitions at ~75% of their estimated 1RM. Subsequent lifts were single repetitions of progressively heavier weights until reaching the 1RM. For both SQ and BP, all participants achieved their 1RM in a maximum of 3 attempts. The test-retest intraclass reliability for the 2 exercise tests was R >0.93 to <0.98 (17). After 48-h of the completion of 1RM tests, the participants performed fourteen-assessment sessions (7 per exercise) separated by 24 to 48-h of rest, alternating SQ and BP. Each session comprised only one repetition to failure (RTF) test using one of the following 1RM percentages: 30%; 40%; 50%; 60%; 70%; 80% and 90%. As the availability of the free weight equipment did not always permit obtaining the exact amount of kg representing the aforementioned percentages, the nearest amount of kg provided it being equal or up to a maximum of 10% greater than the reference was considered. Thus, the following seven ranges were determined: 30 to <40%, 40 to <50%, 50% to <60%, 60 to <70%, 70 to <80%, 80 to <90% and >90%. In order to minimize the accumulated fatigue effect, sequencing of the RTF tests within and between exercises was randomized. Furthermore, participants were asked to abstain from any unaccustomed or hard exercise and refrain from caffeine intake, whilst maintaining similar sleeping hours and daily activities during the testing period. All the assessments were performed during the afternoon (12 to 6:00 pm).

Measurement of movement velocity

An optical rotary encoder (Winlaborat®, Buenos Aires, Argentina, model WLEN01) with a minimum lower position register of 1 mm connected to the proprietary software Real Speed Version 4.20 was used for measuring the position and calculating the velocity (v) in $m \cdot s^{-1}$ achieved during each repetition of RTF test. For both exercises, SQ and BP the cable of the encoder was connected to the right side of the bar in such a way that either exercise could be performed freely over a vertical direction of the movement (25). To avoid underestimation of the neuromuscular performance, changes in movement velocity were estimated by measuring the mean accelerative velocity (MAV) calculated from the accelerative portion of the concentric phase, across which velocity increases until peaking (15). During this phase, the acceleration applying by the exerciser to the barbell is $\geq -9.81\ m \cdot s^{-2}$ (4,5). Four specific measurements of MAV were identified in each RTF test (i) the MAV achieved at the first repetition (MAV-1); (ii) The maximum value of MAV achieved along the set (MAV-max); (iii) the repetition where a drop of ≥10% in the MAV with respect to the MAV-max (MAV-10); and (4) the MAV measured during the last repetition (MAV-F), just before muscular failure. As the maximum movement velocity is not always achieved during the first repetition, particularly when using light to submaximal loads (2) the velocity obtained at the first repetition and the repetition at which the maximal velocity was produced were described independently. A 10% loss in the MAV was chosen because a reduction of such magnitude when performing maximal impulsive exercises has been associated with a significant drop in the mechanical power output (29) associated with a selective fatigue of fast twitch motor unit (14). The criterion analysis to determine the event associated with the MAV-10 was the identification of two continuous repetitions with a ≥10% velocity loss compared to the MAV-max. Furthermore, in order to describe the total drop in movement velocity compared the MAV-max, the MAV-F was also reported.

Measurement of the rating of perceived exertion (RPE)

During the RTF tests the participants were instructed to verbally indicate a number of the OMNI-RES (0–10) scale on each and immediately after the completion of every repetition in both SQ and BP. The investigators used the same simplified question (11) before starting each RTF test: “how much effort have you experienced during the exercise?” A rating of 10 was considered to be the perceived maximum effort to perform the specific assessed exercise (11) and associated with the most stressful task ever performed (18). Conversely, a rating of 0 was associated with no effort (seated or resting), and a rating of 1 corresponded to the perception of effort while performing an extremely easy effort (21). A minimal break (~1 sec) between repetitions was allowed for the participants to report their RPE scores. A large (A3 size 29.7 x 42 cm) figure showing the OMNI–RES (0-10) scale was in full view of participants during the SQ (on the wall, less than 2 m in front) and BP (held by a researcher, about 1 m above).

Dependent Variable

The main dependent variable was the RPE value expressed at the end of each repetition during the RTF test. The suitability of the perceptual response to reflect changes in movement velocity was assessed by the measurements of the RPE values obtained at the previously described velocity measures (MAV-1, MAV-max, MAV-10 and MAV-F). (i) RPE-1: OMNI-RES scale value collected after the first repetition of each set; (ii) RPE-max: OMNI-RES scale value measured where the MAV-max was observed for each set; (iii) RPE-10: OMNI-RES scale value measured when a drop of ≥ 10% respect to MAV-max was identified; (iv) RPE-F: OMNI-RES scale value measured after completing the last repetition of each set.

The test-retest reliability coefficients (ICCs) and standard error of measurement (SEM) for the seven RTF tests were ≥0.92 and between 0.13 to 0.02 $m{\cdot}s^{-1}$ or 0 to 1.8 considering the four critical points measured at the MAV and the OMNI-RES (0-10) scale respectively (4,5),.

Statistical Analyses

Means ± SD were determined for all the variables analyzed during the 1RM and RTF tests. The Shapiro-Francia test was used for testing the normality of the difference data between all possible pairs of within-subject conditions. To analyze the existence of differences between the RPE values measured at the four critical points identified within each set of SQ and BP, two-way (critical points × exercise) repeated measures analysis of variance (ANOVA) was applied for each of the tested data range. Repeated measures ANOVAs were also performed to determine differences between the four perceptual events (RPE-1, RPE-max; RPE-10 and RPE-F) across the seven percentage ranges for SQ and BP. In order to reduce the error variance, sex (men, women) was included as a covariate. Bonferroni-adjusted post-hoc analyses were performed as appropriate for pairwise comparisons. Eta squared (η^2) and Cohen´s *d* values were reported to provide an estimate of standardized effect size (small η^2 = 0.01, d = 0.2; moderate η^2 = 0.06, d=0.5; and large η^2 = 0.14, d = 0.8). In order to provide useful information for controlling the load estimate and training designs, sex-adjusted 95% confidence intervals (CI) were also calculated for the RPE measured at the four analyzed velocity measures across the 7 ranges and exercises. Average values are reported as mean ± SD unless stated otherwise. Significance level was set at 0.05. All analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 20.0; SPSS, Inc., Chicago, IL, USA).

RESULTS

The 1RM mean±SD values for both SQ and BP were: SQ: males 131.9 ± 18.8 kg (1.6 ± 0.3 $kg{\cdot}body\ mass^{-1}$); females 68.5 ± 28.5 (1.0 ± 0.3 $kg{\cdot}body\ mass^{-1}$). BP: males 100.8 ± 13.5 kg (1.2 ± 0.2 $kg{\cdot}body\ mass^{-1}$); females 43.9 ± 6.5 (0.7 ± 0.1 kg body $mass^{-1}$). Table 1 describes the total number of repetitions and MAV measured across ranges at the corresponding critical points in each of the tested ranges for SQ and BP. The adjusted by sexes RPE values measured within and across the 7 seven loading ranges in SQ and BP are described in Table 2.

Table 1. Mean (SD) of the total number of repetitions and MAV measured at the corresponding time points in each of the seven ranges for SQ and BP.

Slot ranges	Squat					Bench Press				
(as %1RM)	Total Reps	MAV-1	MAV-max	MAV-10	MAV-F	Total Reps	MAV-1	MAV-max	MAV-10	MAV-F
30-40	60 ± 16	0.70 ± 0.06	0.76 ± 0.09	0.67 ± 0.08	0.23 ± 0.16	61 ± 10	0.68 ± 0.12	0.84 ± 0.12	0.74 ± 0.11	0.16 ± 0.09
>40-50	43 ± 15	0.65 ± 0.07	0.70 ± 0.06	0.61 ± 0.05	0.17 ± 0.15	43 ± 7	0.61 ± 0.12	0.72 ± 0.12	0.64 ± 0.10	0.19 ± 0.09
>50-60	33 ± 17	0.60 ± 0.08	0.64 ± 0.09	0.56 ± 0.08	0.21 ± 0.14	33 ± 6	0.58 ± 0.09	0.65 ± 0.09	0.57 ± 0.09	0.14 ± 0.04
>60-70	21 ± 5	0.53 ± 0.07	0.54 ± 0.08	0.49 ± 0.07	0.18 ± 0.13	24 ± 4	0.49 ± 0.09	0.56 ± 0.08	0.50 + 0.08	0.16 ± 0.09
>70-80	14 ± 13	0.48 ± 0.06	0.48 ± 0.06	0.42 ± 0.05	0.16 ± 0.12	16 ± 3	0.42 ± 0.07	0.45 ± 0.08	0.39 ± 0.07	0.16 ± 0.06
>80-90	10 ± 2	0.41 ± 0.08	0.41 ± 0.07	0.36 ± 0.06	0.15 ± 0.09	10 ± 2	0.32 ± 0.09	0.35 ± 0.07	0.30 ± 0.07	0.15 ± 0.06
>90-100	5 ± 1	0.34 ± 0.09	0.33 ± 0.08	0.27 ± 0.07	0.15 ± 0.08	5 ± 1	0.25 ± 0.05	0.25 ± 0.05	0.20 ± 0.06	0.12 ± 0.04

MAV: Mean accelerative velocity; **MAV-1**: Mean accelerative velocity achieved during the first repetition; **MAV-max**: highest value of mean accelerative velocity; **MAV-10%**: Mean accelerative velocity measured when a 10% decrease was determined; **MAV-F**: Mean accelerative velocity measured during the last completed repetition.

Table 2. Mean (SD) [95% CI] of the adjusted by sexes RPE values measured at the corresponding critical points in each of the seven ranges for SQ and BP.

Slot ranges (as %1RM)	Squat				Bench Press			
	RPE-1*	RPE-max*	RPE-10†	RPE-F	RPE-1*	RPE-max*	RPE-10‡	RPE-F
30-40 [a]	1.1 ± 0.8 [0.8, 1.4]	1.2 ± 1.0 [0.8, 1.7]	4.4 ± 2.6 [3.5, 5.3]	10 ± 0 [10, 10]	1.6 ± 1.1 [1.0, 2.2]	2.3 ± 1.1 [1.7, 2.9]	3.9 ± 1.5 [3.1, 4.7]	10 ± 0 [10, 10]
> 40-50 [b]	2.1 ± 1.4 [1.4, 2.8]	2.3 ± 1.7 [1.5, 3.2]	4.8 ± 2.1 [4.1, 5.6]	10 ± 0 [10, 10]	2.0 ± 1.2 [1/4, 2.6]	2.9 ± 1.3 [2.2, 3.5]	4.6 ± 2.2 [3.4, 5.8]	10 ± 0 [10, 10]
> 50-60 [c]	2.7 ± 1.5 [2.0, 3.4]	2.9 ± 1.5 [2.2, 3.6]	5.7 ± 1.9 [5.0, 6.4]	10 ± 0 [10, 10]	3.2 ± 1.6 [2.4, 4.0]	3.7 ± 1.6 [2.9, 4.5]	5.4 ± 0.7 [5.1, 5.7]	10 ± 0 [10, 10]
> 60-70 [d]	3.4 ± 1.6 [2.6, 4.2]	4.1 ± 1.7 [3.3, 4.9]	5.8 ± 1.6 [5.0, 6.5]	10 ± 0 [10, 10]	4.0 ± 1.4 [3.3, 4.7]	4.8± 1.0 [4.3, 5.4]	6.1 ± 1.1 [5.6, 6.7]	10 ± 0 [10, 10]
> 70-80 [e]	5.2 ± 1.4 [4.5, 6]	5.6 ± 1.5 [4.9, 6.4]	6.8 ± 1.3 [6.3, 7.4]	10 ± 0 [10, 10]	4.9 ± 1.0 [4.4, 5.4]	5.3 ± 0.9 [4.8, 5.8]	6.8 ± 0.7 [6.4, 7.2]	10 ± 0 [10, 10]
> 80-90 [f]	6.4 ± 0.8 [6.0, 6.9]	6.7 ± 0.9 [6.2, 7.1]	7.8 ± 1.0 [7.4, 8.2]	10 ± 0 [10, 10]	6.2 ± 1.5 [5.4, 7.0]	6.8 ± 1.5 [6.0, 7.6]	7.8 ± 1.2 [7.2, 8.4]	10 ± 0 [10, 10]
> 90-100 [g]	7.6 ± 1.4 [6.9, 8.3]	7.7 ± 1.4 [7.0, 8.4]	8.9 ± 0.7 [8.5, 9.3]	10 ± 0 [10, 10]	7.9 ± 1.0 [7.4, 8.4]	8.0 ± 0.9 [7.5, 8.5]	8.8 ± 0.6 [8.5, 9.2]	10 ± 0 [10, 10]

RPE= rate of perceived exertion from OMNI-RES (0-10) scale; **RPE-1**: RPE value expressed after the first repetition; **RPE-max**: RPE expressed after performing the repetition that produced the maximal mean acceleration velocity; **RPE-10:** RPE value measured when a 10% drop in maximal accelerative velocity was determined; **RPE-F**: RPE value expressed immediately after the set was completed.

Differences within ranges:

[a, f, g] in both SQ and BP, p<0.001 RPE-1 and RPE max vs. RPE-10; and RPE-F; RPE-10 vs. RPE-F.

[b, c, d] in SQ, p<0.001 RPE-1 and RPE max vs. RPE-10; and RPE-F; RPE-10 vs. RPE-F; BP p<0.001 between the four time points.

[e] in both SQ and BP <0.001 between the four time points.

Differences across ranges:

* In both SQ and BP, p<0.001 RPE-1 and RPE max 30-40% vs. all ranges, > 40-50% vs. > 60 to 100%; >50-60% vs. >70 to 100%; > 70-80%, 80-90% and >90-100% vs. all ranges.

RPE-10, †SQ: p<0.05 from the first four ranges (30 to 70%) vs. the last three ranges (>70-100%); p<0.05 between the last three ranges.

‡ BP: 30-40% vs. all ranges; >40-50, >50-60, vs. the last three ranges (>70-100%); >70-80 vs. >90-100%; >80-90, vs >90-100%.

RPE-F, all p >0.05.

Differences between exercises (SQ vs. BP): All p > 0.05

Comparison of the RPE values measured in SQ and BP within each loading range

Significant interaction (critical points × exercise) effect was observed only for the first three ranges (30-40%, >40-50% and >50-60%), no other interactions were determined. Main effect of critical points was determined in all the seven ranges for both SQ and BP, while an effect of exercise was observed only for the lightest range (30-40%). No exercise effect was determined for the other 6 ranges. Results from the all conducted ANOVAs are included as supplementary material.

As described in Table 2, no differences between exercises were identified for the four analyzed critical points (RPE-1, RPE-max, RPE-10 and RPE-F) in the seven assessed ranges. In overall, for both SQ and BP, the scores of RPE-1 and RPE-max were lower than the scores measured for the RPE-10 (all d >0.8). The RPE-F elicited the maximum score in all cases being significantly higher (d>0.8) than the other three critical points.

Comparison of the RPE values measured in SQ and BP across the loading ranges

Main effects for range were observed for the RPE-1 and RPE-max, while no statistically significant effect ($p = 0.064$, $\eta^2 = 0.027$) was determined for RPE-10 across ranges. Conversely, while no exercise effect was observed for the RPE-1 and RPE-max, a significant effect of the exercise was identified for the RPE-10 (see supplementary material). Overall, the RPE-1 and RPE-max were progressively increasing as the loading ranges increased. The perceptual values measured at the beginning of the sets and when the MAV reach the maximum were lower at 30-40% respect to all other six ranges (all d > 0.8). The RPE-1 and RPE-max at >40-50% and >50-60% were lower than the observed at >60 to 100% and >70 to 100% respectively (all d > 0.80). Although for both SQ and BP, the RPE-10 was similar between ranges, the values measured between 30 to 70% were lower compared to those observed at the higher three ranges (all d > 0.8). The RPE-10 expressed at the last three ranges was different between them in both SQ and BP (Table 2).

As no significant differences were observed between the two analyzed exercises, the values of Table 3, merging the RPE means and 95% CI from SQ and BP can be used to select the load (RPE-1) or to estimate changes in movement velocity (RPE-max or RPE-10) during continuous sets indistinctly for both SQ and BP.

Table 3. Confidence Intervals (CI, 95%) determined on the RPE variables determined along the seven-repetition to failure test merging both exercises (SQ and BP).

1 RM ranges	RPE-1/RPE-max*		RPE-10%		RPE-F	
	Lower	Upper	Lower	Upper	Lower	Upper
30 to <40%	1	2	4	5	10	10
40 to <50%	2	3	4	5	10	10
50 to <60%	2	4	5	6	10	10
60 to <70%	3	4	6	6	10	10
70 to <80%	5	6	6	7	10	10
80 to <90%	6	7	7	8	10	10
>90 to 100%	7	8	9	9	10	10

*Note: as the RPE-1 and RPE-max produced almost identical values they are reported together.
RPE-1 indicates OMNI-RES scale value determined after doing the first repetition of each repetition to failure test. RPE-max indicates OMNI-RES scale value of the repetition where the maximal mean accelerative velocity was reached in each repetition to failure test. RPE-10% indicates OMNI-RES scale value expressed when a 10% decrease in the mean accelerative velocity was determined along each repetition to failure test. RPE-F indicates the OMNI-RES scale value expressed after performing the last repetition of each ach repetition to failure test.

DISCUSSION

We confirmed the applicability of the RPE to identifying velocity changes during continuous sets to volitional failure over a broad-loading range and to discriminate loading-zone based on 10% slots (from 30 to 100% of 1RM) in both SQ and BP. Our findings suggest that the RPE values measured by the OMNI-RES (0-10) scale at the beginning of the set (RPE-1), when movement velocity peaks (RPE-max) or drops by ≤10% compared to the maximum (RPE-10) or after completion of the last repetition of every set (RPE-F) are not different between SQ and BP. These results permit the acceptance of our hypothesis asserting that the RPE values associated with the aforementioned critical points are similar for upper and lower body exercises.

Opposite to Mayo et al. (22) who reported higher RPE values for the parallel squat than in the bench press after performing sets to failure or not to failure, we found no differences between the OMNI-RES scores measured in SQ and BP either when comparing the RPE scores within and between the seven assessed loading-ranges. Discrepancies in methodologies can explain controversies between studies. Mayo and colleagues measured the perceptual response of the active muscles (19) focused on the participants' feelings on pectoralis major in the bench press, and on the gluteus maximus, quadriceps and hamstrings in the parallel squat. Our participants were instructed to report the perception of effort experienced by the whole body (33) without focusing on one particular body region. Indeed, in our study, all the participants, regardless of the exercises and loading range, expressing the maximal RPE score at failure, while in the Mayo and colleagues' study, the participants limiting the perception of effort to a restricted body area, increasing the influence of the recruited muscle mass on the resulting subjective response. This criterion explains the lower scores in bench press compared to the squat along with the submaximal RPEs values even when the sets were conducted until failure.

The analysis across ranges indicates that the RPE-1 is a practical and useful reference to discriminate loading zones. The observed results are in line with previous studies with powerlifters (12,13) supporting the use of subjective measures to estimate the relative load and proximity to failure as an alternative to traditional methods such as percentage of 1RM. At this point, it is important to highlight that the reference 1RM assessment was determined 48-h before conducting all the RTF tests. All the participants completed the assessments in less than 4 weeks. Within such as a relatively short period of time, it is unlikely to observe substantial changes on strength performance in resistance-trained individuals who maintained a low volume training stimulus represented by the RTF testing sessions (27). However, it is also possible that nonidentified small (~5%) day-to-day fluctuations of strength performance still occurs (6) and could have impacted on the accuracy of the tested relative loading-ranges as well as on the reported RPE-1. Nevertheless, the observed total number of repetitions per range and the corresponding MAV-1 and MAV-max are very similar to those reported in previous studies using the same exercises (4,5).

We confirmed the use of OMNI-RES scale as an effective tool to measure the perception of effort on a repetition-by-repetition basis using reference values that can be indistinctly applied for upper and lower body exercises. Within the context of the limitation of RPE scales (11) the appropriate use of the perceptual response emerges as an alternative or complementary method for being applied with similar criteria as the velocity control training (16,35). To illustrate, instead of prescribing a target number of repetitions per set, an opened workout configuration is indicated with each set interrupted when athletes are unable to maintain a previously established velocity threshold, i.e. ≥ 90% of the maximum achieved at the beginning of the workout (36). As suggested by Pérez-Castilla et al. due to very large between-participants variability in the number of repetitions that could be performed before reaching a given velocity loss (e.g. ~10%), it is recommended to pre-establish a minimum and maximum number of repetitions per set, and then use the recorded velocity to decide when the set should be stopped within the desired range of repetitions (31). In line with the previous rationale, the RPE scores expressed at the beginning and over an ongoing set can be used to select the training load and with pre-established perceptual threshold scores to stop the set when the RPE reaches a non-desired value.

The present study is not without limitations. The participants were young, recreationally resistance-trained, aiming to improve their body image rather than enhancing their strength or power output. They were familiarized with a controlled pattern of exercise execution, minimizing the impulsion during the concentric phase. Therefore, the present results cannot be fully applied to other athletic populations trained to perform fast impulsive (e.g. weightlifters) or ballistic (e.g. jumper or throwers) movements. Additionally, it is important to highlight that the reference metric measure of movement velocity used in this study was the MAV and therefore caution should be taken when using the OMNI-RES (0-10) scale to estimate changes of other velocity measures such as peak velocity [maximum instantaneous velocity value reached during the concentric phase at a given load (10)] or mean propulsive velocity [mean velocity value from the start of the concentric phase until the force generated by the bar and the received acceleration applied by the exerciser is lower than the force generated by the bar due to the action of gravity (15)].

In conclusion, the present investigation provides generalized instructions applicable to both upper and lower body exercises on how to the use OMNI-RES (0-10) scale to both estimate the relative amount of the load and to monitor changes of the movement velocity during continuous set to muscular failure using the same reference values for upper and lower body resistance exercises.

PRACTICAL APPLICATIONS

The most relevant contribution of the present investigation is to provide generalized instructions applicable to both upper and lower body exercises on how to the use OMNI-RES (0-10) scale in resistance training. The 95% CIs for the RPE-analyzed variables depicted in Table 3 can be applied to females and males as an approach to distinguish different resistance loading zones, estimate initial changes of the movement velocity (~10% drop) or proximity to self-estimated muscular failure (OMNI-RES approaching 10). For example, at the beginning of the workout an athlete can select the initial load based on the RPE expressed after the first repetition (RPE-1), i.e. ~3 to 4 for 60<70% 1RM, or 5 to 6 for 70<80% 1RM. Athletes will be instructed to exercise with a maximal possible impulse considering that OMNI-RES values of 6 or 7, are indicative of ≥10% velocity loss. Such a drop is not desirable when looking for increasing mechanical power output and minimizing metabolic stress (35).

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The present manuscript has been read and approved by authors.

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