CONTROL OF RESISTANCE TRAINING INTENSITY BY THE OMNI PERCEIVED EXERTION SCALE

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1Department of Fundaments of Motricity and Training, Faculty of Physical Activity and Sport Sciences, European University of Madrid (UEM), Madrid, Spain; 2Sports Department, Faculty of Physical Activity and Sport Sciences—INEF, Technical University of Madrid (UPM), Madrid, Spain; 3Department of Exercise and Wellness, Arizona State University, Mesa, Arizona; and 4Department of Health, Leisure, and Exercise Science, Appalachian State University, Boone, North Carolina

ABSTRACT

Naclerio, F, Rodriguez-Romo, G, Barriopedro-Moro, Mi, Jiménez, A, Alvar, BA, and Tripplett, NT. Control of resistance training intensity by the omni perceived exertion scale. J Strength Cond Res 25(7): 1879–1888, 2011—The purpose of this study was to determine the applicability of the rating of perceived exertion (RPE) scale as a means of controlling resistance training intensity and establishing the relationship between the RPE value, load, and mechanical power (MP) produced during the bench press. Eleven men (22.1 ± 1.0 years) were evaluated on 8 separate days with 48 hours of rest between sessions. After determining the 1 repetition maximum (1RM) value, each subject underwent 7 tests until achieving muscular failure with the following percentage ranges: 30–40, >40–50, >50–60, >60–70, >70–80, >80–90, and >90%. A rotary encoder and the OMNI-RES (0–10) scale were used to estimate the power and to determine the perception of effort (RPE) expressed after each repetition of each set. The RPE produced from the start to the end of each set was related to the percentage of the load and the variability of the MP measured. Additionally, except for the >90% range, significant differences (p < 0.05) between the initial RPE (RPE I) and the average RPE of the first 3 repetitions (RPE 1_3 rep) with respect to the RPE produced with a 10% reduction in MP were identified for all the ranges. These relationships demonstrate the utility of RPE for controlling resistance training intensity.

KEY WORDS load, perception of effort, strength zones, muscle failure, maximal velocity, upper body exercise

INTRODUCTION

Resistance training is an essential component of all training programs in sports and health. Therefore, the quantification and control of variables such as intensity, volume, and frequency, and their relationship to training goals (such as increasing strength, power, and muscular hypertrophy or endurance), is essential to have an accurate exercise prescription (37). One of the most important variables to consider in the development of the optimal resistance training prescription is exercise intensity. Controlling intensity is a key factor in relating the type of adaptation and goal achievement for differing training programs (15). However, intensity for resistance training has many definitions. In some cases, resistance training intensity has been associated with the percentage of 1 repetition maximum (1RM) load (13) or the resistance associated with a specific number of repetitions per set where an RM target, such as a 10RM, or an RM target zone, such as a 6–8RM, is used to prescribe intensity (37).

However, when considering the velocity of the movement in addition to the load, the intensity of strength training can be further estimated by the mechanical power (MP) produced in each action (20), and other parameters such as electromyographic activity (6). In fact, several studies have shown significant coefficients of correlation between intensity and volume of resistance training exercise with the muscle electromyographic activity (22,31), or other metabolic variables like blood lactate or ammonia concentration (7).

Nevertheless, because of a lack of practical application of these methodologies being applied continuously during each training session, researchers have sought easier methodology to quantify intensity. One possibility is linking the magnitude of muscular effort to the rating of perceived exertion (RPE) measured by a numeric scale at the end of each exercise set (8,30,33) and 20 minutes after the conclusion of a workout (8,32). Although the RPE was originally applied to control the aerobic training intensity during cyclic exercise, such as running or cycling (14), more recently, this method has been shown to be effectively
applied as a means of controlling the intensity of other types and even more intense exercises, such as jumping or resistance exercise (21,24), with both men and women (16,30), children, youth, and the elderly (28,29).

According to Robertson et al. (30), the perception of physical exertion is defined as "the subjective intensity of effort, strain, discomfort, and/or fatigue that you feel during exercise." Robertson et al. developed the OMNI Perceived Exertion Scale for Resistance Exercise (OMNI-RES). The OMNI-RES (see Figure 1) has both verbal and mode-specific pictorial descriptors distributed along a comparatively narrow response range of 0–10 (30). These characteristics make the OMNI scale easier for health-fitness practitioners to use as compared to other scales previously published. The original 0–10 scale is thought to be a useful methodology to control the intensity of resistance training (33), but the picture linked to the numerical and verbal reference has been shown to improve the reliability of this scale to control the intensity of resistance training (27,28).

The concurrent validity of the OMNI-RES was established using total weight lifted and blood lactate concentration as criterion variables (30). The results of this investigation demonstrated positive linear regression coefficients ($r = 0.79–0.91$) between RPE (active muscle and overall body), and the 2 criterion variables when 4, 8, or 12 repetitions of the knee extension and biceps curl exercises were performed at 65% of the 1RM by a group of young men and women.

Different from the study by Robertson et al. (30) who examined 2 single-joint exercises, Lagally et al. (21) analyzed the perception of effort measured by a 15-category Borg perceived exertion scale produced by a group of recreational and novice resistance training women after 2 sets of bench press (multijoint exercise) at 60 and 80% of 1RM. The authors found that global, or feelings of whole-body exertion, and the local muscular RPE were significantly related to the percentage of IRM load and electromyographic muscle activity during the workout. However, it is important to note that in this study the repetitions performed did not achieve muscle failure, and it is known that RPE increases as a function of the number of repetitions irrespective of the magnitude of each particular load (30).

Therefore, the application of RPE to control resistance training intensity should be at the beginning of the set to estimate the amount of resistance used and at the end to reflect the relative effort performed by the subject. However, no previous study has applied this type of methodology to control resistance training intensity at the beginning and at the end of the exercise sets. Additionally, there are few studies that have measured resistance training exercise power or velocity during the continuous sets until muscular failure. Izquierdo et al. (19) observed a significant fall in movement velocity at 34–40 or 48–69% of the maximum possible number of repetitions to muscular failure with the 60, 65, 70, and 75% of IRM in the bench press and squat, respectively. In this study, the authors analyzed the velocity reached in all the repetitions of each set but did not control or measure the exertion perceived by the subject during or at the end of each test.

Only limited research has examined the relationship between resistance training intensity and the rating of perceived exertion (RPE), and none of them has analyzed the association of the perception and power with different IRM percentages during a maximum repetition set until muscular failure. Thus, the purpose of this study was to determine the ability of the OMNI-RES (0–10) scale to control the resistance training intensity and to establish the potential relationships between the RPE values obtained by OMNI-RES (0–10) scale, and the load and MP produced during a set until muscular failure using different percentages of IRM in a free weight bench press exercise (multijoint exercise). To reach these objectives, the following hypotheses were formulated: (a) The RPE expressed at the beginning of each set (between the first and the third repetitions) allowed for the identification of the percentage of IRM used; (b) The RPE expressed within the set (at the end of each repetition) reflected the change in the power output and allowed for the identification of the moment where the power fell below 90% with respect to the maximum produced at the start of each set.

**METHODS**

**Experimental Approach to the Problem**

This study was designed to examine the applicability of
the RPE OMNI-RES (RPE) as a means of determining the percentage of the load and controlling the change of the MP produced during the continuous repetition set until failure with different percentages of the 1RM (ranging from 30 to 90%) in the bench press exercise. After determining the 1RM value, 11 men were evaluated on 7 occasions with a submaximal load until achieving muscular failure with the following 1RM percentage ranges: 30–40, 40–50, 50–60, 60–70, 70–80, 80–90, and 90%. The power and the RPE OMNI-RES value were determined for all the repetitions of each set to find if there was any relationship between the RPE within the 7 sets to failure, especially at the moment where the power fell below 90% of the maximum value achieved at the beginning of the set.

Subjects
Eleven male students volunteered for the study (22.1 ± 1.0 years, 81.5 ± 10.3 kg, and 179.6 ± 6.6 cm). All subjects were recreationally resistance trained, with a minimum of 2 years and a maximum of 5 years doing this type of training. None of the subjects participated in any other competitive sports activities for at least 2 years before the study. All subjects were training systematically with the free weight bench press exercise in their normal workout for at least 6 months before the beginning of the study. All participants reported not having taking any banned substances as declared by the International Olympic Committee 2008 antidoping rules (34) and not having any upper body muscular injuries for at least 1 year before the beginning of the study. Before participating in this study, all subjects read and signed an informed consent previously approved by the University’s Institutional Review Board.

Procedures
Figure 2 shows a diagram of the study, which included an initial familiarization period and 8 evaluation sessions.

Familiarization Period. Before the beginning of the study, all the subjects underwent 8 familiarization sessions to use the OMNI-RES 0–10 scale proposed by Robertson et al. (30). For this period, the subjects followed their normal workouts that comprised 3 sets of 8–10 repetitions of 6–8 resistance exercises of different muscle groups (upper, middle, and lower body) including the bench press. During these sessions, the subjects received standard instructions, and the procedures were explained to indicate the rating of perceived effort.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep tot</td>
<td>Total repetitions determined in each submaximal corresponding set to failure.</td>
</tr>
<tr>
<td>Rep-10%</td>
<td>Repetition number where a 10% decrease in mechanical power was determined.</td>
</tr>
<tr>
<td>%Rep-10%</td>
<td>Repetition percentage where the mechanical power fell below 10% with respect</td>
</tr>
<tr>
<td></td>
<td>to the maximal power produced during a corresponding set.</td>
</tr>
<tr>
<td>AP_max</td>
<td>Maximal average power achieved during the corresponding set.</td>
</tr>
<tr>
<td>AP_10%</td>
<td>Average power (watts) determined when a 10% decrease was produced during</td>
</tr>
<tr>
<td></td>
<td>each corresponding set.</td>
</tr>
<tr>
<td>AP_1_3</td>
<td>Average power (watts) measured during the last repetition of each</td>
</tr>
<tr>
<td></td>
<td>corresponding set.</td>
</tr>
<tr>
<td>RPE 1_3 rep</td>
<td>OMNI-RES scale value of the first 3 repetitions of each corresponding set.</td>
</tr>
<tr>
<td>RPE_10%</td>
<td>OMNI-RES scale value produced when a 10% decrease in average power was</td>
</tr>
<tr>
<td></td>
<td>determined along each corresponding set.</td>
</tr>
<tr>
<td>RPE I</td>
<td>OMNI-RES scale value determined after doing the first repetition of each</td>
</tr>
<tr>
<td></td>
<td>corresponding set.</td>
</tr>
<tr>
<td>RPE F</td>
<td>OMNI-RES scale value produced immediately after the end of each corresponding</td>
</tr>
<tr>
<td></td>
<td>set.</td>
</tr>
</tbody>
</table>

*RPE = rating of perceived exertion.
The flat bench press exercise with free weights was performed using Olympic bars and weights according to the technique described by Escamilla et al. (10). During each movement, the subjects were required to apply the maximal possible force to reach the maximum velocity and power during the concentric phase, to keep their hips on the bench, and the bar had to travel from touching the chest to full arm extension for a complete repetition. No chest bouncing was permitted, and their grip was between the outer ring and inner edge of the bar knurling on a standard Olympic bar (no close grip or wide grip was allowed).

**Exercise.** The flat bench press exercise with free weights was performed using Olympic bars and weights according to the technique described by Escamilla et al. (10). During each movement, the subjects were required to apply the maximal possible force to reach the maximum velocity and power during the concentric phase, to keep their hips on the bench, and the bar had to travel from touching the chest to full arm extension for a complete repetition. No chest bouncing was permitted, and their grip was between the outer ring and inner edge of the bar knurling on a standard Olympic bar (no close grip or wide grip was allowed).

**Evaluation Sessions.** The 1RM bench press according to methodology proposed by Baechle et al. (1) was determined in the first session. Based on the 1RM results obtained for each subject, 7 percentage evaluation ranges were determined: 30–40, >40–50, >50–60, >60–70, >70–80, >80–90, and >90%. These ranges were used to test the number of repetitions needed at 7 submaximal loads to achieve muscular failure. Each subject was evaluated on 7 occasions with a load comprised between each of the 7 percentage ranges previously mentioned. To minimize the accumulated fatigue effect, sequencing of the submaximal tests was randomized.

**Control of Mechanical Power.** An optical rotary encoder (Real Power, Globus, Italy) with a minimum lower position register of 1 mm was used for measuring the position and calculating the velocity, force, and power applied during each repetition of all submaximal bench press exercise tests. The cable of the encoder was connected to the bar in such a way that the exercise could be performed freely. The encoder’s method of functioning enabled the cable to move in either vertical direction of the movement, sending the position of the bar every millisecond (1,000 Hz) to an interface that was connected to a computer. Proprietary software for the encoder (Real Power J110) was used to calculate the peak and average force in Newtons (N), velocity in meters per second (v), and power in watts (W) produced during the concentric phase of each exercise repetition.

The analysis of the MP produced during the submaximal test to failure was based on specific moments determined when the MP had a 10% fall with respect to their maximum produced at the beginning (first to third repetitions) of the set because this power decline has been associated with

### Table 2. Mean ± SD of the repetition variables determined in each percentage range evaluated.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>30–40%</th>
<th>&gt;40–50%</th>
<th>&gt;50–60%</th>
<th>&gt;60–70%</th>
<th>&gt;70–80%</th>
<th>&gt;80–90%</th>
<th>&gt;90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep tot</td>
<td>46.0 ± 7.4</td>
<td>34.4 ± 5.9</td>
<td>26.0 ± 4.2</td>
<td>18.0 ± 4.2</td>
<td>13.0 ± 2.6</td>
<td>7.8 ± 2.1</td>
<td>4.7 ± 0.9</td>
</tr>
<tr>
<td>Rep-10%</td>
<td>15.1 ± 5.0</td>
<td>13.8 ± 5.3</td>
<td>9.5 ± 3.4</td>
<td>6.6 ± 3.0</td>
<td>4.7 ± 2.2</td>
<td>3.3 ± 0.9</td>
<td>3.3 ± 0.5</td>
</tr>
<tr>
<td>%Rep-10%</td>
<td>33.4 ± 11.9</td>
<td>40.0 ± 12.2</td>
<td>37.6 ± 11.8</td>
<td>34.1 ± 12.4</td>
<td>32.5 ± 14.6</td>
<td>39.6 ± 15.8</td>
<td>70.0 ± 13.5</td>
</tr>
</tbody>
</table>

*Rep tot = total repetitions determined in each submaximal corresponding set to failure; Rep-10% = repetition number where a 10% decrease in mechanical power was determined; %Rep-10% = repetition percentage where the mechanical power fell below 10% with respect to the maximal power produced during a corresponding set.

### Table 3. Mean ± SD of the mechanical power variables determined in each evaluated range.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>30–40%</th>
<th>&gt;40–50%</th>
<th>&gt;50–60%</th>
<th>&gt;60–70%</th>
<th>&gt;70–80%</th>
<th>&gt;80–90%</th>
<th>&gt;90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP_max</td>
<td>309.5 ± 86.9</td>
<td>351.4 ± 121.5</td>
<td>327.1 ± 95.9</td>
<td>326.5 ± 79.6</td>
<td>300.5 ± 87.8</td>
<td>251.3 ± 83.8</td>
<td>235.1 ± 66.7</td>
</tr>
<tr>
<td>AP_1_3</td>
<td>278.4 ± 82.4</td>
<td>319.2 ± 115.7</td>
<td>297.0 ± 87.8</td>
<td>308.1 ± 81.7</td>
<td>281.9 ± 88.6</td>
<td>225.8 ± 80.1</td>
<td>200.1 ± 45.5</td>
</tr>
<tr>
<td>AP_10%</td>
<td>263.9 ± 75.0</td>
<td>273.6 ± 67.7</td>
<td>276.9 ± 85.8</td>
<td>280.4 ± 67.6</td>
<td>248.1 ± 74.1</td>
<td>200.1 ± 65.2</td>
<td>180.7 ± 50.5</td>
</tr>
<tr>
<td>AP_min</td>
<td>59.1 ± 21.3</td>
<td>96.6 ± 123.6</td>
<td>81.0 ± 41.6</td>
<td>130.4 ± 82.6</td>
<td>89.0 ± 47.0</td>
<td>100.6 ± 55.0</td>
<td>112.3 ± 34.2</td>
</tr>
</tbody>
</table>

*AP_max = maximal average power achieved during the corresponding set; AP_1_3 rep = mean average power of the first 3 repetitions of each corresponding set; AP_10% = average power (watts) determined when a 10% decrease was produced during each corresponding set; AP_min = average power (watts) measured during the last repetition of each corresponding set.
a selective fast twitch fiber (FTF) fatigue and a loss of movement speed not recommended for power or velocity athletes (18,35). The criterion analysis to determine this point of MP reduction was the performance of 2 continuous repetitions with a 10% reduction in MP with respect to the maximum value produced at the beginning of the set. Control of the Rating of Perceived Exertion. During the submaximal tests, the subjects were instructed to report the RPE value indicating a number of the OMNI-RES (0–10) scale at the end of each repetition. Subjects were asked to use any number on the scale to rate their overall muscular effort, and the investigators used the same question, "how hard do you feel your muscles are working," each time (23). A rating of 0 was to be associated with no effort (rest), and a rating of 10 was considered to be maximal effort and associated with the most stressful exercise ever performed (8). An experienced, certified strength and conditioning coach supervised all testing and recorded the RPE value at the end of all repetitions of each submaximal exercise test. Table 1 shows a review of all variables analyzed during the submaximal test. The reliability of the submaximal test used in this study was demonstrated in a series of previous pilot studies that found test–retest intraclass correlation coefficients >0.92. Statistical Analyses Mean (M) and SDs were determined for all of the variables analyzed during the 1RM and submaximal tests. The Friedman test was applied to identify any differences between the MP and RPE variable determined in each corresponding submaximal test and across each submaximal range. For post hoc comparisons, the Tukey test was used. The $\eta^2$ statistic provided estimates of the effect sizes. The mean confidence interval (CI) was determined at 95% to estimate the RPE for

![Figure 3. Comparison between the mechanical power-related variables determined along all the ranges assessed in the study. *p < 0.05: from AP_max and AP_1_3 with respect to AP_10%, and AP_min and from AP_10% with respect to AP_min. #: p < 0.05: from AP_max with respect to AP_10% and AP_min and from AP_10% and AP_1_3 with respect to AP_min. β: p < 0.05: from AP_max with respect to AP_min. AP_max indicates maximal average power achieved during the corresponding set. AP_1_3 indicates mean average power of the first 3 repetitions of each corresponding set. AP_10% indicates average power (watts) determined when a 10% decrease was produced during each corresponding set. AP_min indicates average power (watts) measured during the last repetition of each corresponding set.]

![Table 4. Mean ± SD of the variables related to the RPE determined in each evaluated range.*](attachment:table4.png)

<table>
<thead>
<tr>
<th>Variables</th>
<th>30–40%</th>
<th>&gt;40–50%</th>
<th>&gt;50–60%</th>
<th>&gt;60–70%</th>
<th>&gt;70–80%</th>
<th>&gt;80–90%</th>
<th>&gt;90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPE I</td>
<td>2.2 ± 1.2</td>
<td>2.3 ± 1.2</td>
<td>2.1 ± 1.7</td>
<td>2.8 ± 2.2</td>
<td>6.4 ± 1.1</td>
<td>7.0 ± 1.1</td>
<td>8.0 ± 0.1</td>
</tr>
<tr>
<td>RPE 1_3 rep</td>
<td>2.2 ± 1.2</td>
<td>2.4 ± 1.4</td>
<td>2.2 ± 1.6</td>
<td>3.2 ± 2.2</td>
<td>6.8 ± 1.0</td>
<td>7.7 ± 1.1</td>
<td>8.6 ± 0.2</td>
</tr>
<tr>
<td>RPE_10%</td>
<td>4.4 ± 1.7</td>
<td>5.5 ± 1.7</td>
<td>4.4 ± 1.3</td>
<td>6.0 ± 1.8</td>
<td>7.8 ± 1.0</td>
<td>8.4 ± 1.2</td>
<td>9.3 ± 0.3</td>
</tr>
<tr>
<td>RPE F</td>
<td>9.8 ± 0.4</td>
<td>9.8 ± 0.3</td>
<td>9.9 ± 0.3</td>
<td>9.7 ± 0.7</td>
<td>9.8 ± 0.6</td>
<td>10.0 ± 0.2</td>
<td>10.0 ± 0.1</td>
</tr>
</tbody>
</table>

*RPE I = OMNI-RES scale value determined after doing the first repetition of each corresponding set; RPE 1_3 rep = OMNI-RES scale value of the first 3 repetitions of each corresponding set; RPE_10% = OMNI-RES scale value produced when a 10% decrease in average power was determined along each corresponding set; RPE F = OMNI-RES scale value produced immediately after the end of each corresponding set.
each submaximal test. The level of significance was set at 0.05. Statistical power for the evaluations ranged from 0.85 to 1.00. The data collected were processed using the SPSS v.15.0 program for Windows.

**RESULTS**

The 1RM average value was 81.5 ± 10.4 kg.

**Submaximal Test Repetition**

Table 2 shows the descriptive results of the repetition variables measured in each of the 7 ranges evaluated.

The Friedman test showed significant differences between the Rep tot ($X^2(6) = 52.16; \ p < 0.001; \ \eta^2 = 0.90$), Rep-10% ($X^2(6) = 37.37; \ p < 0.001; \ \eta^2 = 0.64$) and the %Rep-10% ($X^2(6) = 21.84; \ p < 0.001; \ \eta^2 = 0.32$) determined in each range. The Tukey post hoc test showed that except between 70–80 and 80–90% and from this range to the last one (>90%), there were significant differences between the Rep tot produced by all the ranges assessed ($p < 0.05$). With respect to the %Rep-10%, significant differences ($p < 0.01$) were found between all ranges except between the first (30–40%) and the second range (40–50%). On the other hand, for the %Rep-10% significant differences were found between the last range (>90%), which showed a higher significant percentage of decline ($p < 0.01$), with respect to the other ranges, which showed a similar % Rep-10%.

**Analysis of the Average Mechanical Power**

Table 3 shows the descriptive results of the MP variables measured in each of the 7 ranges evaluated.

The Friedman test showed significant differences between the $\#Rep_10\%$ ($X^2(6) = 37.4; \ p < 0.001; \ \eta^2 = 0.91$), $\#Rep_10\%$ ($X^2(2) = 37.4; \ p < 0.001; \ \eta^2 = 0.91$), $\#Rep_10\%$ ($X^2(6) = 41.31; \ p < 0.001; \ \eta^2 = 0.85$), and the %Rep-10% ($X^2(6) = 21.84; \ p < 0.001; \ \eta^2 = 0.32$) determined in each range. The Tukey post hoc test showed that except between 70–80 and 80–90% and from this range to the last one (>90%), there were significant differences between the Rep tot produced by all the ranges assessed ($p < 0.05$). With respect to the %Rep-10%, significant differences ($p < 0.01$) were found between all ranges except between the first (30–40%) and the second range (40–50%). On the other hand, for the %Rep-10% significant differences were found between the last range (>90%), which showed a higher significant percentage of decline ($p < 0.01$), with respect to the other ranges, which showed a similar % Rep-10%.
TABLE 5. Mean CI (95%) determined on the RPE variables measured along the 7 submaximal tests.∗

<table>
<thead>
<tr>
<th>1RM ranges (%)</th>
<th>RPE I</th>
<th>RPE 1–3 rep</th>
<th>RPE_10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>30–40</td>
<td>1.32</td>
<td>3.08</td>
<td>1.32</td>
</tr>
<tr>
<td>&gt;40–50</td>
<td>1.47</td>
<td>3.07</td>
<td>1.45</td>
</tr>
<tr>
<td>&gt;50–60</td>
<td>0.95</td>
<td>3.23</td>
<td>1.12</td>
</tr>
<tr>
<td>&gt;60–70</td>
<td>1.07</td>
<td>4.49</td>
<td>1.52</td>
</tr>
<tr>
<td>&gt;70–80</td>
<td>5.61</td>
<td>7.12</td>
<td>6.13</td>
</tr>
<tr>
<td>&gt;80–90</td>
<td>6.25</td>
<td>7.75</td>
<td>6.87</td>
</tr>
<tr>
<td>&gt;90</td>
<td>8.00</td>
<td>8.00</td>
<td>8.48</td>
</tr>
</tbody>
</table>

∗CI = confidence interval; RPE = rating of perceived exertion; RPE I = OMNI-RES scale value determined after doing the first repetition of each corresponding set; RPE 1_3 rep = OMNI-RES scale value of the first 3 repetitions of each corresponding set; RPE_10% = OMNI-RES scale value produced when a 10% decrease in average power was determined along each corresponding set.

>50–60% \( (X^2(2) = 39.85; \ p < 0.001; \ \eta^2 = 0.87) \), >60–70% \( (X^2(2) = 34.8; \ p < 0.001; \ \eta^2 = 0.92) \), >70–80% \( (X^2(2) = 41.22; \ p < 0.001; \ \eta^2 = 0.89) \), >80–90% \( (X^2(2) = 29.82; \ p < 0.001; \ \eta^2 = 0.84) \) and >90% \( (X^2(2) = 10.10; \ p < 0.001; \ \eta^2 = 0.87) \).

For the first 3 ranges (>30–40, >40–50, and >50–60%), the Tukey post hoc test showed significant differences \( (p < 0.05) \) between the AP_max and AP_1_3 with respect to the AP_10% and AP_min. Also, there were significant differences between AP_10% to AP_min \( (p < 0.005) \) (see Figure 3).

For the fourth range (>60–70%), there were significant differences between AP_max with respect to AP_10%, and AP_min \( (p < 0.05) \) and between AP_min with respect to AP_1_3, AP_10% \( (p < 0.05) \) but not between the AP_1_3 and AP_10% (see Figure 3). For the last 3 ranges (>70–80, >80–90, and >90%), significant differences were found only between AP_max and AP_min \( (p < 0.05) \) (see Figure 3).

Analysis of the Rating of Perceived Exertion
Table 4 shows the descriptive results of the RPE variables measured in each of the 7 ranges evaluated. The Friedman test showed significant differences when comparing the RPE I, RPE 1_3 rep, RPE_10% and RPE F in each of the evaluated ranges; 30–40% \( (X^2(3) = 39.96; \ p < 0.001; \ \eta^2 = 0.97) \), >40–50% \( (X^2(3) = 43.23; \ p < 0.001; \ \eta^2 = 0.99) \), >50–60% \( (X^2(3) = 42.20; \ p < 0.001; \ \eta^2 = 0.97) \), >60–70\% \( (X^2(3) = 35.50; \ p < 0.001; \ \eta^2 = 0.94) \), >70–80\% \( (X^2(3) = 37.75; \ p < 0.001; \ \eta^2 = 0.87) \), >80–90\% \( (X^2(3) = 25.00; \ p < 0.001; \ \eta^2 = 0.95) \), and >90% \( (X^2(3) = 9.70; \ p < 0.001; \ \eta^2 = 0.99) \).

For the first 4 ranges (>30–40, >40–50 >50–60, and >60–70%), the Tukey post hoc test showed significant differences \( (p < 0.01) \) from RPE I, RPE 1_3 rep to the RPE_10% and RPE F (see Figure 4). For the fifth and sixth ranges (>70–80 and >80–90%), significant differences were found \( (p < 0.05) \) between RPE I and RPE 1_3 rep with respect to RPE_10% and RPE F (see Figure 4). For the last range (>90%), significant differences were found \( (p < 0.05) \) between RPE I and RPE 1_3 rep with respect to RPE F (see Figure 4).

When comparing the average value of the RPE associated variables, the Friedman test showed significant differences for the following variables RPE I \( (X^2(6) = 37.74; \ p < 0.001; \ \eta^2 = 0.74) \), RPE 1_3 rep \( (X^2(6) = 36.86; \ p < 0.001; \ \eta^2 = 0.77) \), and RPE_10% \( (X^2(6) = 37.37; \ p < 0.001; \ \eta^2 = 0.61) \) but not for the RPE F \( (X^2(6) = 7.73; \ p = 0.258; \ \eta^2 = 0.06) \).

The Tukey post hoc test did not show any significant differences between any of the 4 variables for the first 4 ranges (30–70%) nor for the last 3 ranges (70–>90%). Nevertheless, for the first 4 ranges,
significant differences ($p < 0.05$) were found between the value of RPE I, RPE 1_3 rep, and RPE_10% with respect to those values determined at the last 3 ranges (see Figure 5).

Confidence Intervals

Table 5 depicts the mean CIs (95%) determined for the first 4 RPE variables, which show significant differences along submaximal tests.

**DISCUSSION**

The results of this study indicate that the RPE OMNI-RES scale is a valuable tool for controlling the initial load (% 1RM) and power fluctuation during a continuous repetition set until the volitional fatigue. This approach used the perception of effort at the beginning (RPE I), and at different times over the continuous set, and could allow for controlling the zone or type of resistance training done by the athletes during each session. Nevertheless, the results of this study indicate that neither the RPE I nor the RPE 1_3 rep have any load difference across the first 4 ranges (>30–70% of 1RM). However, the 2 RPE variables are good indicators for differentiating loads associated with the first 4 ranges (>30–70% of 1RM) from the last 3 ranges (>70–100% of 1RM). These results permit us to accept the first hypothesis of using the RPE OMNI-RES value to differentiate a light or moderate 1RM percentage (<70%) from moderate to high ones (>70%), but we have to reject this hypothesis if we want to make a more selective discrimination along the different percentages of 1RM load. The increase in the perceived exertion response produced after the first repetition of each set (RPE I) shows a nonlinear path that was similar to the relationship described by Pincivero et al. (26) with a leg extension exercise. However, these results are different from other studies where the relationship between the RPE expressed at the end of the set and the percentage of 1RM was shown to be linear (25,36). However, in all of these studies, this relationship was established with a single-joint dynamic exercise such as leg extension (25) or an isometric single-joint exercise such as arm abduction (36). It is also possible that some methodological differences regarding the type of exercise, the period of familiarization, the subject characteristics regarding their level of performance, and the type of scale selected in our study (OMNI-RES that included a picture description vs. the nonpictorial CR-10 scale) may have influenced the selection of the number of the scale.

With respect to the MP produced along the sets, for the first 4 ranges (30–60% of 1RM), we also did not find any significant difference between the AP_max and AP_1_3. Although with moderate to high load (>70% 1RM) the maximal power can be achieved at the first repetition, with light load (<70% 1RM) the maximal neural input and motor unit recruitment required to elicit the maximal muscular activation to accelerate the bar for producing the maximal MP may require 1 or 2 previous repetitions to activate the maximal neural discharge from the neural-motor system (4). These results are similar to those achieved by Baker and Newton (5), who analyzed the MP produced during a set of 10 repetitions with 45 and 35% of 1RM in the bench press throw and jump squat, respectively, in a group of well-trained basketball players. In this study, maximal average power was produced in the third repetition for the bench press and in the second repetition for the jump squat. However, in the Baker and Newton study, the authors did not make any measurement or relationship between the MP and the number of repetitions with RPE during the 2 exercises.

However, in our opinion, the principal finding of this study was the relationship between the MP variability and RPE produced along each submaximal set to muscular failure with different percentages of the 1RM range. Figure 3 shows that the RPE I and RPE 1_3 rep are different not only from the RPE F but also from the RPE_10% along the entire evaluated range period. This distinguishes different resistance training zones according to the magnitude of the load expressed as a 1RM percentage. Additionally, it distinguishes the power produced in each repetition because the RPE value expressed along the sets was related to the moment where power fell below 10% with respect to the maximum power achieved at the beginning of the set. This finding allows us to accept the second hypothesis because the variation expressed in the OMNI-RES scale value

![Figure 7](image-url). Lower and upper ranges of rating of perceived exertion (RPE) expressed when the power output during the set fell 10% below the maximum produced with different ranges of the 1 repetition maximum (1RM) percentage. RPE_10% indicates OMNI-RES scale value produced when a 10% decrease in average power was determined along each corresponding set.
reflects the variation of the average power measured along each repetition of the set performed with different 1RM percentages.

In terms of professional application, if an individual’s goal is to improve muscular power, the resistance training movements should be done with the maximal velocity to achieve the higher possible MP and should never fall below the 90% of the maximum (18,35). Therefore, the RPE mean CIs depicted in Table 5 can be used to select the magnitude of the load and to estimate the variability of the MP produced along a continuum of multijoint upper body exercises such as the free weight bench press. According to this approach, for improving muscular power with a load between 30 and 60% of 1RM the set should begin with a load that is equated to an RPE I between 1 and 3 (expressed immediately after doing the first repetition) and the set should be finished before the subject expresses an RPE value of 4. Alternately, to improve muscular power with heavier loads (>60–80% of 1RM, the RPE I should be between 1 and 5, and the set should be finished before the subject expresses a value of 6 when exercising in the load range of >60 to 70%, whereas for the load range which comprised >70 to 80%, the RPE I should be between 6 and 7 and the set should be completed before an RPE value reaches 8. For maximal force-oriented training where the load is >80% of 1RM (2,17), the RPE I should be about 6 or more increasing suddenly to over 8 on the third repetition or to a point of 10 if the percentage of the load is >90% of 1RM.

Figures 6 and 7 depict the range for each percentage of 1RM associated with the 3 different strength training zones where the right and left limits of each bars are determined by the inferior and superior mean CIs shown in Table 5 and calculated for the RPE I and RPE 10% for each % 1RM range assessed in the bench press exercise. Therefore, the value of RPE I depicted in Figure 6 allows the coach or athlete to select the initial load, whereas the range of RPE values depicted in Figure 7 should be used to determine when the set must be finished or stopped.

Although significant differences were found with respect to the repetition number where maximal MP was achieved in the different ranges, except for the highest ranges the analysis shows that the percentage of the repetitions associated with a 10% reduction in MP (%Rep-10%) was once again similar except in the highest range (>90%) (see Table 2). These results were similar to the results obtained by Izquierdo et al. (19), but these authors used an analysis of variance with repeated measures to determine a significant loss in the velocity of the barbell along different sets of bench press to failure. In this work, the significant loss of barbell velocity was associated with a 13% fall in vertical velocity. However, it is important to note that a 10% loss in the velocity or MP is associated with a selective FTF fatigue and an increase in the activation of the slow twitch fibers that allows the continuation of the exercise with a progressively lower velocity (9,15).

The determination of this key point along a continuous set in different resistance training exercises such as a bench press is essential to avoid negative adaptation especially in athletes training for power, because these athletes have to maintain their maximal force as a means of increasing power or movement velocity. This is indeed the case of throwers, tennis players, and some team sports such as soccer, volleyball, or basketball. The systematic failure of not adequately controlling resistance training with sets, which are too long (too many repetitions), where the power and velocity fall (<10% of the maximal power) arriving near or at the muscular failure at all loads ranging from 40 to 95% 1RM, have been related to changes in mechanical and morphological properties of FTF Iib to a less explosive fiber (FTF Ila) and eventually to a slower and less-fatigable one (FTF Ila) (12,15). These changes have been related to a decrease in the proportion of myosin heavy chain (MHC) type IIX isoform to a stronger but slower MHC type IIA isoform caused by a 6–15RM resistance training range (3).

However, the results of this study have several limitations because we have analyzed only 1 upper body exercise, and therefore, our results cannot be applied to other exercises, especially if there are significant mechanical differences (i.e., a single-joint exercise such as arm curl or cyclic total body exercises such as cycle ergometer or running) or employ different muscle groups (i.e., lower body like leg press or squat), which have been shown to produce different effort perceptions at the same percentage and repetitions when compared to upper body exercises (11). Also, we did not measure the variability of the RPE nor the power along a complete session of resistance training with more general exercises, including 3–4 sets of 6–8 or even more exercises. However, if the goal is to train the explosive power zone, the coach has to consider working at maximal power level, avoiding a significant loss of power, in all the principal exercises used during the session.

In conclusion, this is the first study in which the RPE OMNII-RES scale was applied at the beginning to estimate the relative amount of the load and at the end of a set to control the training zone approached during the resistance training. Our results support the RPE OMNII-RES scale proposed by Robertson et al. (30) as a useful tool for controlling the fluctuation of intensity produced during the set of continuous repetitions, when performed in a multijoint upper body resistance exercise.

Practical Applications

Our findings, as in other previous studies (8,21,30), support the utility of the perception of effort to select the percentage of the load (% 1RM) to determine the initial intensity and control the variation of the power along a continuum set to determine the strength training zone that the athletes should train in each training session for upper body exercises. Unlike other studies, in our work, we give the coach the possibility of using the RPE at the beginning to determine the amount of load related to the

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IRM percentage range and at the end to control the decline of the power below a desirable level during a set of several repetitions. This is especially important for those athletes who need to improve their muscular power and to maintain a high level of work intensity, where the power never falls >10% with respect to their maximum. This new application of RPE OMNI-RES offers to coaches the possibility of reducing exercise prescription mistakes during resistance training without the need for velocity or force transducers or similar devices and allows a more precise control of training intensity or the variability of power and velocity produced during resistance training exercises.

REFERENCES