Rest Interval Required for Power Training With Power Load in the Bench Press Throw Exercise

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Abstract

Hernández Davó, JL, Sabido-Solana, R, Sarabia-Marín, JM, Fernández Fernández, J, and Moya Ramón, M. Rest interval required for power training with power load in the bench press throw exercise. *J Strength Cond Res* 30(5): 1265–1274, 2016–This study aimed to test the influence of various rest interval (RI) durations used between sets on power output performance and physiological and perceptual variables during a strength training session using 40% of the 1 repetition maximum (1RM) in the bench press throw exercise. Thirty-one college students (18 males and 13 females) took part in the study. The experimental protocol consists of 5 sets of 8 repetitions of the bench press throw exercise with a load representing 40% of 1RM. Subjects performed the experimental protocol on 3 different occasions, differing by the RI between sets (1, 2, or 3 minutes). During the sessions, power data (mean power and peak power), physiological (lactate concentration [La^+]) and perceptual (rating of perceived exertion) variables were measured. In addition, delayed onset muscular soreness was reported 24 and 48 hours after the training session. One-way repeated-measures analysis of variance showed that 1-minute RI entailed higher power decreases and greater increases in values of physiological and perceptual variables compared with both 2- and 3-minute RIs. Nevertheless, no differences were found between 2- and 3-minute RIs. Therefore, this study showed that, when training with 40% of 1RM in the bench press throw exercise, a 2-minute RI between sets can be enough to avoid significant decreases in power output. Consequently, training sessions' duration could be reduced without causing excessive fatigue, allowing additional time to focus on other conditioning priorities.

Key Words resistance training, power training, optimal load

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30(5)/1265–1274

Journal of Strength and Conditioning Research

Introduction

Strength training is accepted as an essential constituent of training programs, independent of an individuals' goal (41). With the objective to obtain a specific target, strength training prescription involves the combination of several variables, including types of exercises used; intensity (% 1-repetition maximum [1RM] or repetition maximum load); volume (sets × repetitions); exercise sequence within a strength training session; repetition velocity; training frequency; and rest interval (RI) length between sets (21). Among these variables, RI between sets has received little attention. Current studies indicate that the RI between sets is a critical variable affecting both acute and chronic adaptations to strength training program (6). Thus, researchers have suggested different RIs between sets (30–300 seconds) depending on the specific training goal of the strength training program.

When training for maximal strength, 3–5 minutes between sets produces greater increases in absolute strength because of the maintenance of higher volumes and intensities during the sessions (44), whereas when targeting muscular hypertrophy, a shorter RI (30–60 seconds) may cause greater acute elevations in several hormones (e.g., growth factor) linked to increases in muscle size (16,20). Concerning muscular endurance, the findings are unclear, although short RIs (20–60 seconds) seem to increase muscular endurance performance, as shown by higher repetition velocities and greater torque produced during a cycle test after training (9,15). Finally, research has shown higher levels of muscular power output over multiple sets when comparing long (3–5 minutes) with short (1 minute) RIs (1). Nevertheless, several authors have found no differences in acute power output production across incremental loads (0–60 kg) between different RIs (1–4 minutes) during jump squats (Nibali et al. 2014) or in power output decreases after 6 sets of squat exercise when comparing 1-, 2-, and 3-minute RIs (Martorelli et al. 2014). Regarding chronic adaptations on power output, Pincivero et al. (29) showed greater improvements in peak power (PP) in a long RI group (160 seconds) compared with a short RI group (40 seconds) after 4 weeks of isokinetic knee extension training. Conversely, Robinson et al. (35) did not find influence of different RIs (30 vs. 90 vs. 180 seconds) on vertical jump power output improvements after 5 weeks of training, whereas Ramirez-Campillo et al. (2014) did not show differences in countermovement jump performance after 7 weeks of explosive training between the 3 groups of training intervention (30-, 60-, or 120-second RI).

Therefore, there are conflicting findings about the influence of RI on acute responses and chronic muscular power adaptations. From a physiological point of view, power performance is highly dependent on anaerobic energy metabolism (primarily the phosphagen system), which requires a minimum of 4 minutes for its full replenishment (14). Abdessemed et al. (1) showed significant decreases in power output and significant increases in lactate concentration ($[La^+]$) when comparing 1-minute RI to 3-minute and 5-minute RIs during bench press performed at 70% of 1RM. Nevertheless, Willardson and Burkett (44) showed no differences in strength gains comparing 2- vs. 4-minute RI despite the higher total volume performed by the 4-minute RI group (7,200 vs. 5,800 kg per mesocycle, approximately). Another important factor to consider regarding submaximal intensity lifts is whether sets are performed to failure. If sets are not performed to failure, then a 2-minute RI could be taxing because of reduced metabolic demand (38). Jones et al. (18) reported a trend for improvements in explosive outcomes (PP and peak velocity in loaded [30 and 50% 1RM] jump squats) in the light-load group after 10 weeks of training compared with the heavy-load group using the same RI (2 minutes).

Furthermore, in an upper-body power training session, the use of relatively low external loads (which maximize power output) and number of repetitions may allow the maintenance of power output over multiple sets with shorter RI. The greater influence of neural factors (e.g., motor unit recruitment and firing frequencies) in power training may induce a different type of fatigue compared with traditional (metabolic-dependent) resistance training (Buckthorpe et al. 2014). The use of loads that maximize power output has been suggested to provide an effective stimulus to elicit increases in maximal power output, leading to an efficient development of power production and dynamic athletic performance (13,45).

However, despite the wide number of studies that have sought the RI required to maintain the training volume during strength training (i.e., number of repetitions up to failure), no studies have examined the influence of RI on acute power output maintenance when a light load is used in the bench press throw exercise. Therefore, the aim of this study was to check the influence of different RIs for subject's ability to maintain power output during a power training session using 40% of 1RM in the bench press throw exercise.

Methods

Experimental Approach to the Problem

The study followed a within-subjects study design that examined the effects of RI between sets on power output performance and psycho-biological variables during the bench press throw exercise. Each participant attended 4 laboratory sessions in a 4-week period. The first session consisted of a 1RM test (bench press). The other 3 sessions consisted on the same strength training protocol (e.g., 5 sets of 8 repetitions), using 40% of 1RM for the bench-press throw exercise, but experiencing a different RI (e.g., 1-, 2-, or 3-minute) variables analyzed were mean power (MP), PP, $[La^+]$, rating of perceived exertion (RPE), and delayed onset muscular soreness 24 (DOMS 24) and 48 (DOMS 48) hours postsession. All subjects were familiarized with all equipment used for testing and training, and 2 familiarization sessions were performed 1 week before the first testing session. Familiarization sessions consisted of 3 sets of 8 repetitions of the bench press throw exercise using 40% of the subject's subjective 1RM. Furthermore, in an attempt to avoid diurnal variation in test measures, subjects were scheduled at approximately the same time for each testing and training session. To limit experimental variability, the same qualified investigator conducted all testing sessions.

Subjects

Thirty-one physically active college students, 18 males (age = 24 ± 3 years (range 21–34 years); height = 1.79 ± 0.06 m; mass = 74 ± 10 kg; 1RM = 92 ± 19 kg) and thirteen females (age = 24 ± 3 years (range 19–30); height = 1.64 ± 0.06 m; mass = 60 ± 3 kg; 1RM = 41 ± 5 kg), took part in this study. All males and females were physically active with at least 12 months of experience in strength training and were currently performing strength training sessions at least 2 $d \cdot wk^{-1}$. In addition, males were required to bench press at least 100% of their body weight, whereas females were required to bench press at least 60% of their body weight. All subjects completed a health history questionnaire to document that they were free of cardiovascular disease, physiological disorders, or any other illness that may have increased the risk of participation or introduced unwanted variability into the results. All subjects were instructed to maintain their normal life habits. Throughout the investigation, participants were requested to maintain their regular diets and normal hydration state, not to take any nutritional supplementation or anti-inflammatory medications, and to refrain from caffeine intake in the 3 hours before each testing session. Strength training sessions were not allowed at least 72 hours before the experimental sessions. Before participation, each subject provided written informed consent approved by the Ethics Committee of the University Miguel Hernández of Elche in accordance with the Declaration of Helsinki. The study conforms to the Code of Ethics of the World Medical Association (approved by the ethics advisory board of Swansea University) and required players to provide informed consent before participation.

Procedures

Maximal Dynamic Strength Assessment. The 1RM test for the bench press was performed using a Smith Machine (Multipower M953; Technogym, Gambettola, Italy). Kinematic data were recorded by linking a rotary encoder to 1 end of the bar (T-Force system, Ergotech, Spain), which recorded the position of the bar with an analog-to-digital conversion rate of 1,000 Hz and an accuracy of 0.0002 m (11). The linear transducer was interfaced to a personal computer by means of a 14-bit analog-to-digital data acquisition board, where a specialized software application (T-Force Dynamic Measurement System) automatically calculated the relevant kinematic and kinetic parameters. Bar velocity was calculated by differentiation of bar displacement data with respect to time; then, instantaneous acceleration (a) was obtained through differentiation of velocity-time data. Instantaneous force (F) was calculated as $F = m\,(a + g)$, where m is the moving mass (in kilogram) manually entered into the software and g is acceleration due to gravity ($9.81\ \mathrm{m \cdot s^{-2}}$). Finally, instantaneous mechanical power output (P) was calculated as the product of vertical force and bar velocity ($P = F \times v$). Peak power was taken as the maximum value of the power-time curve. The validity and reliability of this system have been previously established, with ICC values ranging from 0.81 to 0.91 and a coefficient of variation <3.6% (10). For power variables analysis, only the propulsive concentric phase (without barbell flying) was analyzed. The 1RM bench press was assessed using a previously established protocol (7), which requires that subjects progressively increase resistance across attempts (e.g., beginning with 40 and 20 kg for males and females, respectively) until the 1RM is achieved. The rest period between trials was at least 5 minutes. Subjects began by lying horizontally with the feet, gluteus maximus, lower back, upper back, and head firmly planted on the bench with elbows fully extended and gripping the bar. Subjects lowered the bar until it lightly touched the chest, approximately 3 cm superior to the xiphoid process. The elbows were extended equally with the head, hips, and feet remaining in contact with the floor throughout the lift. No bouncing or arching of the back was allowed. Testing was conducted by the same researcher and all conditions were standardized.

Experimental Protocol. Three minutes after a warm-up consisting of 2 sets of 10 repetitions with the individual participant using 50% of 1RM, subjects performed 5 sets of 8 repetitions with a load representing 40% of 1RM. Based on several studies (16,17,23), a load of 40% of 1RM can be considered as appropriate load to maximize power output in the bench press throw exercise. In addition, very similar protocols have been used in the literature when testing for power responses (Cormie et al. 2010; Lyttle et al. 1996). Subjects performed the experimental protocol in 3 sessions that varied the RI between sets (1, 2, or 3 minutes). The order of the sessions was randomized. Through each set, subjects were encouraged to throw the barbell as high as possible, and during each throw, they were required to keep their head, shoulders, and trunk in contact with the bench and their feet in contact with the floor. No bouncing of the barbell was allowed. During the tests, both MP and PP outputs were recorded using the software provided by the T-Force system. For the data analysis, the following variables were calculated: MP and PP in each set, the percentage of change in both MP and PP with regard to the values obtained in the first set, and PP of each repetition.

[La⁺] Measures. [La⁺] was determined from 25 μl capillary blood samples drawn from the earlobe and analyzed with a portable device (Lactate Scout, Senselab, Germany), with an accuracy of $0.1\ \mathrm{mmol \cdot L^{-1}}$ (39). Samples were taken 1 minute before and after each protocol and analyzed at these time points by the portable lactate analyzer.

Perceptual Variables. Rating of perceived exertion values were obtained using the Borg category scale (CR-10) (2). The CR-10 scale consists of a scale of exercise intensity defined

TABLE 1. Physiological and perceptual data.*†

Rest interval	[La⁺] before ($\mathrm{mmol \cdot L^{-1}}$)	[La⁺] after ($\mathrm{mmol \cdot L^{-1}}$)	[La⁺] increase ($\mathrm{mmol \cdot L^{-1}}$)	RPE	DOMS 24	DOMS 48
Males (min)						
1	3.9 ± 0.9	6.4 ± 1.1‡	2.5 ± 0.9‡	6.5 ± 1.6‡§	2.4 ± 1.8‡	1.5 ± 1.3‡
2	4.1 ± 0.9	6 ± 0.9	2 ± 0.9	5.2 ± 1.6	2.8 ± 2.2‡	1.6 ± 2.1
3	4 ± 0.5	5.3 ± 0.7	1.3 ± 0.6	4.7 ± 1.6	1.2 ± 1.3	0.4 ± 0.5
Females (min)						
1	2.8 ± 0.4	4.6 ± 0.6	1.8 ± 0.4‡§	4.8 ± 1.5‡	2.2 ± 2	1 ± 1.2
2	2.8 ± 0.4	3.9 ± 0.8	1.1 ± 0.7	4.3 ± 1.9	2.2 ± 1.5	1.1 ± 1.2
3	3.1 ± 0.8	4 ± 1	0.9 ± 0.6	3.8 ± 1.4	1.5 ± 1.3	0.8 ± 0.9

*[La⁺] = blood lactate concentration; RPE = rating of perceived exertion; DOMS 24 = delayed onset muscular soreness 24-hour postsession; DOMS 48 = delayed onset muscular soreness 48-hour postsession.
†Values are mean ± *SD*.
‡Significant differences ($p \le 0.05$) with 3-minute rest interval.
§Significant differences ($p \le 0.05$) with 2-minute rest interval.

Table 2. Kinematic data by rest interval in both males and females.*†

	Load (kg)	Time to PP (ms)	Time to RFDmax (ms)	Concentric phase (ms)	Flying time (ms)
Males (min)	35.3 ± 7.8				
1		379 ± 45	43 ± 30	736 ± 63	280 ± 16
2		369 ± 42	58 ± 37	725 ± 56	289 ± 17
3		383 ± 42	46 ± 29	733 ± 48	297 ± 19‡
Females (min)	15.6 ± 1.6				
1		437 ± 44	81 ± 26	804 ± 42	313 ± 20
2		436 ± 53	78 ± 33	805 ± 51	314 ± 27
3		424 ± 56	71 ± 36	795 ± 51	319 ± 24

*PP = peak power; RFDmax = maximum rate of force development.
†Values are mean ± *SD*.
‡Significant difference ($p \leq 0.05$) with 1-minute rest interval.

between "rest" (0) and "maximal" (10). Subjects were asked, "How hard do you feel the exercise was?" immediately after the last set of each protocol.

Delayed onset muscular soreness (DOMS) was reported by the subjects 24 and 48 hours after each session. Subjects were asked, "How painful do your muscles feel?" giving their subjective feeling on a 0–10 scale (0 = no pain; 10 = a lot of pain) (28). All subjects reported no DOMS before all testing sessions.

Statistical Analyses

All data were analyzed using the statistical package SPSS 18.0 (SPSS Inc., Chicago, IL, USA). The normality of the outcome measures was tested using the Kolmogorov-Smirnov test. Owing to statistical between-gender differences in 1RM, MP, PP, [La+], and RPE, data of males and females were analyzed separately. A 1-way repeated-measure analysis of variance was used to evaluate the RI (1 vs. 2 vs. 3 minutes) influence in variables related to (a) mechanical (MP and PP), (b) physiological ([La+]), and (c) perceptual (RPE and DOMS) variables. Statistical significance was set at $p \leq 0.05$. Cohen's d and the standardized mean difference were used to calculate effect sizes (mean difference/pooled *SD*) and interpreted for a recreationally trained sample according to Rhea (33), as $d < 0.35$ (trivial), 0.35–0.80 (small), 0.80–1.50 (moderate), and >1.5 (large).

Results

Physiological and Perceptual Variables

The physiological and perceptual variables analyzed ([La+], RPE, and DOMS 24 and 48 hours) for the 3 different RIs are shown in Table 1.

Males showed significantly higher values in [La+] after ($d = 1.19$), [La+] increase ($d = 1.53$), RPE ($d = 1.08$), DOMS 24 ($d = 0.75$), and DOMS 48 ($d = 1.11$) when using the 1-minute RI compared with the 3-minute RI ($p \leq 0.05$). Rating of perceived exertion values were higher with the 1-minute RI ($d = 0.79$) compared with the 2-minute rest protocol. Moreover, comparing the 2-minute with the 3-minute RI, only DOMS 24 was significantly higher ($d = 0.9$) when using the 2-minute RI ($p \leq 0.05$).

Females showed significantly higher values in [La+] increase when using the 1-minute RI compared with both

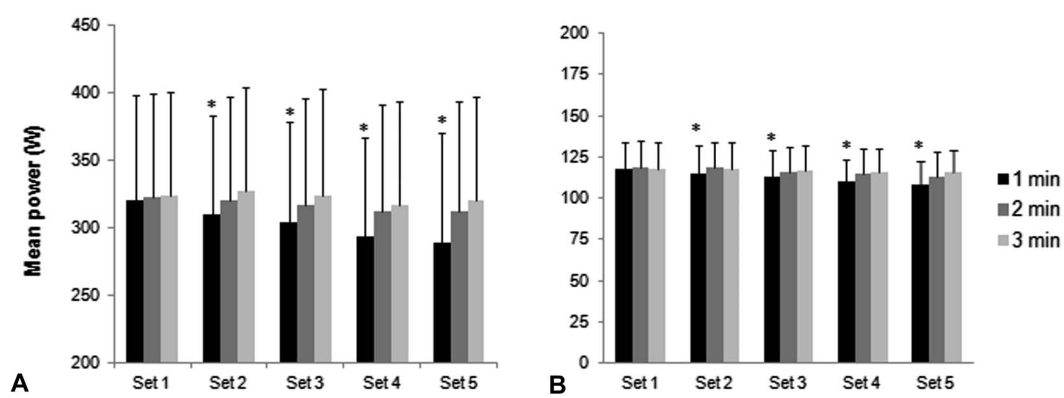

Figure 1. Mean power (MP) values (±*SD*) obtained in males (A) and females (B) with the different rest interval used. *Significant differences ($p \leq 0.05$) with the first set.

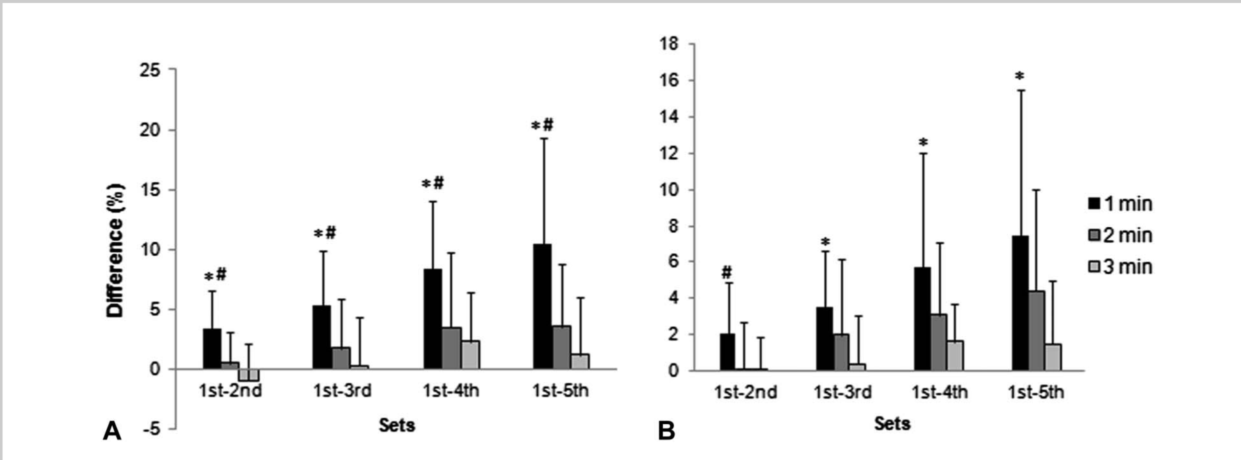

Figure 2. Mean percent change ($\pm SD$) in mean power obtained in males (A) and females (B) with the different rest interval (RI) used. *Significant differences ($p \leq 0.05$) with 2-minute RI; #significant differences ($p \leq 0.05$) with 3-minute RI.

the 2-minute ($d = 1.3$) and the 3-minute RI ($d = 1.82$) ($p \leq 0.05$). Results also showed significantly higher RPE values when using the 1-minute RI compared with the 3-minute RI ($d = 0.68$) ($p \leq 0.05$).

Kinematic Variables

Data of kinematic variables are summarized in Table 2. Among all variables, only the barbell flying time showed significant differences between RI conditions in males, which were higher (297 vs. 280 milliseconds; $d = 0.97$), when the 3-minute RI was compared with the 1-minute RI. There were no significant differences in time to PP, time to maximum rate of force development, or concentric phase time, neither in males nor in females.

Power-Related Variables

Mean Power. Mean power data for each RI are showed in Figures 1A, B (males and females). Significant decreases ($p \leq 0.05$) in MP were observed for the 1-minute RI started from the second set in both males and females. Comparing the values with the first set, MP values were lower in the second (321 vs. 309 W; $d = 0.15$), third (321 vs. 303 W; $d = 0.23$), fourth (321 vs. 294 W, $d = 0.36$), and fifth set (321 vs. 288 W; $d = 0.41$) in males. In females, MP values were lower in the second (118 vs. 115 W; $d = 0.19$), third (118 vs. 113 W; $d = 0.31$), fourth (118 vs. 110 W; $d = 0.55$), and fifth set (118 vs. 108 W; $d = 0.67$).

Percent changes in MP comparing the RI protocols are presented in Figure 2. In males, the relative changes in MP

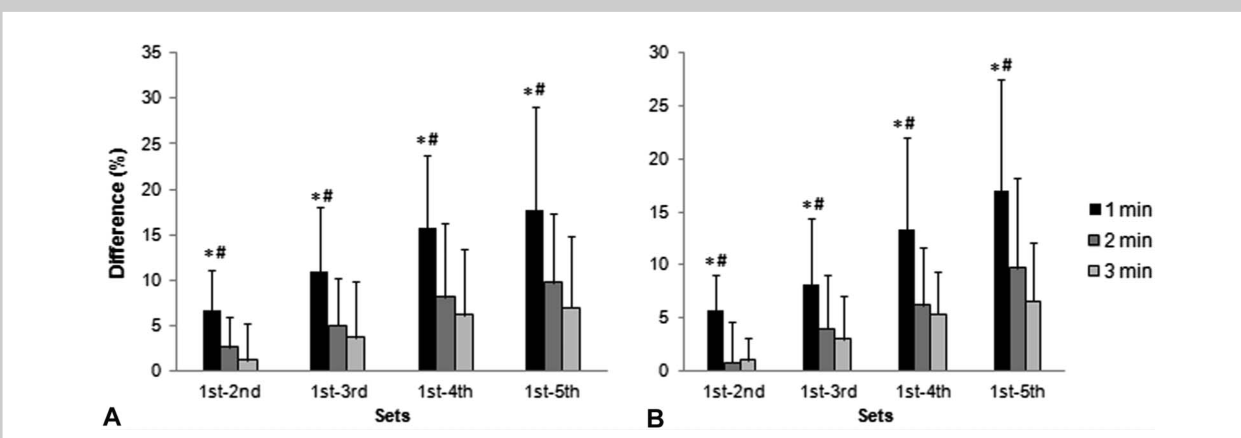

Figure 3. Mean percent change ($\pm SD$) in peak power obtained in males (A) and females (B) with the different rest interval (RI) used. *Significant differences ($p \leq 0.05$) with 2-minute RI; #significant differences ($p \leq 0.05$) with 3-minute RI.

Table 3. Peak power values within sets by rest interval in males.*

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Average
1 min									
Set 1	632	634	618	604	586†	566†	546†	528†	589
Set 2	618	602	587	562†	537†	517†	501†	482†	551‡
Set 3	586	581	571	543†	508†	495†	475†	449†	526‡
Set 4	564	557	537†	514†	478†	460†	443†	428†	498‡
Set 5	559	559	538†	513†	473†	449†	427†	413†	491‡
2 min									
Set 1	650	643	631	609†	592†	574†	559†	537†	600
Set 2	645	636	623	590†	576†	557†	540†	518†	586
Set 3	634	618	615	592†	569†	545†	522†	499†	574‡
Set 4	620	605	594	569†	557†	530†	511†	476†	558‡
Set 5	608	598	584	565†	541†	513†	500†	475†	548‡
3 min									
Set 1	666	666	640	625†	606†	582†	565†	544†	612
Set 2	669	655	634†	618†	593†	579†	559†	536†	605
Set 3	652	640	627†	598†	584†	565†	538†	521†	591
Set 4	645	627	608†	582†	568†	546†	532†	501†	576‡
Set 5	635	620	603	584†	566†	535†	529†	496†	571‡

*Values are expressed in watts.
†Significantly lower ($p \leq 0.05$) than the first repetition of the set.
‡Significantly lower ($p \leq 0.05$) than the first set.

values were significantly higher when using the 1-minute RI compared with the 2- and 3-minute RIs from the second to the fifth set ($p \leq 0.05$). When comparing the 1-minute RI with the 2-minute RI, reported values ranged between 3.4 vs. 0.5% (second set) and 10.5 vs. 3.6% (fifth set) ($d = 0.82–0.99$), whereas reported values comparing the 1-minute RI with the 3-minute RI were 3.4 vs. −0.9% (second set) to 10.5 vs. 1.2% (fifth set) ($d = 1.18–1.39$). In females, results showed

Table 4. Peak power values within sets by rest interval in females.*

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Average
1 min									
Set 1	234	230	228	223	217†	212†	208†	200†	219
Set 2	227	226	216†	210†	203†	198†	190†	184†	207‡
Set 3	224	221	215†	202†	194†	188†	180†	173†	200‡
Set 4	214	210	207†	195†	183†	175†	169†	159†	189‡
Set 5	210	205	200†	186†	169†	166†	158†	148†	180‡
2 min									
Set 1	235	233	227	219†	211†	209†	200†	193†	216
Set 2	235	231	226	218†	211†	205†	198†	188†	214
Set 3	228	224	220†	212†	207†	199†	189†	180†	207
Set 4	223	221	214	204†	199†	192†	184†	179†	202‡
Set 5	221	216	208†	196†	191†	180†	174†	166†	194‡
3 min									
Set 1	237	230	226	219†	214†	211†	201†	194†	216
Set 2	232	232	221†	215†	207†	207†	202†	197†	214
Set 3	228	227	221	212†	208†	201†	196†	185†	210
Set 4	221	221	215	206†	200†	197†	188†	187†	204‡
Set 5	222	222	207†	204†	198†	195†	185†	179†	202‡

*Values are expressed in watts.
†Significantly lower ($p \leq 0.05$) than the first repetition of the set.
‡Significantly lower ($p \leq 0.05$) than the first set.

TABLE 5. Peak power decrease (%) in the last repetition of each set when compared to the last repetition of the first set.

	Second set	Third set	Fourth set	Fifth set
Males (min)				
1	9 ± 5.4*†	15.8 ± 9.8*†	19.6 ± 7.9*†	22.9 ± 13.3*†
2	3.9 ± 5.8	7.7 ± 7.2	12.5 ± 9.8	12.7 ± 10.2
3	1.5 ± 7.1	4.1 ± 10.4	8.1 ± 9.7	8.9 ± 11
Females (min)				
1	8 ± 3.9†‡	12.9 ± 7.5*†	19.9 ± 11.2*†	25.2 ± 12.9*†
2	2.6 ± 5.1	7 ± 4.6	7.8 ± 7.6	14.3 ± 10.3
3	−2 ± 8.4	4.5 ± 6.8	2.9 ± 8.2	7 ± 8.2

*Significant differences ($p \leq 0.05$) with 2-minute rest interval.
†Significant differences ($p < 0.01$) with 3-minute rest interval.
‡Significant differences ($p < 0.01$) with 2-minute rest interval.

significant differences between the 1-minute and the 3-minute RI, with the 1-minute RI showing higher decreases ($p \leq 0.05$) from the third (3.5 vs. 0.4%) to the fifth set (7.5 vs. 1.5%) (d = 0.87–1.07). In addition, a significantly greater decrease ($p \leq 0.05$) in MP output was found in the 1-minute RI compared with the 2-minute RI only in the second set (2.1 vs. 0.1%, d = 0.74).

Peak Power. Figure 3 shows the relative decrease in PP output for each RI over the sets in both males (A) and females (B). In males, the relative decrease in PP in the 1-minute RI was significantly higher compared with both 2- and 3-minute RIs from the second to the fifth set ($p \leq 0.05$). Comparing the 1-minute RI vs. the 2-minute RI, the percent change in PP values was significantly higher ($p \leq 0.05$) for 1-minute RI from the second (6.6 vs. 2.6%) to the fifth (17.7 vs. 9.7%) set (d = 0.83–1). In addition, the percent change in PP was significantly higher ($p \leq 0.05$) in the 1-minute RI compared with the 3-minute RI from the second (6.6 vs. 1.2%) to the fifth (17.7 vs. 7%) set (d = 1.09–1.25). In females, results showed significant differences when comparing the 1-minute RI with both the 2- and 3-minute RIs from the second to the fifth set ($p \leq 0.05$). Thus, significantly greater decreases in PP were found when the 1-minute RI was compared with the 2-minute RI from the second (5.7 vs. 0.8%) to the fifth set (17 vs. 9.7%) (d = 0.75–1.34). Comparing the 1-minute RI with 3-minute RI, significantly greater decreases were also found in PP for the 1-minute RI: 5.7 vs. 1% (second set) to 17 vs. 6.6% (fifth set) (d = 0.99–1.66).

Peak power data with each RI are shown in Tables 3 and 4 (males and females). In males, significant decreases ($p \leq 0.05$) in PP were observed for the 1-minute RI starting from the second set: d = 0.23 (second set), 0.41 (third set), 0.6 (fourth set), and 0.61 (fifth set), for the 2-minute RI starting from the third set: d = 0.16 (third set), 0.27 (fourth set), and 0.32 (fifth set), and for the 3-minute RI starting from the fourth set: d = 0.22 (fourth set) and 0.25 (fifth set). In females, significant PP decreases ($p \leq 0.05$) were observed for the 1-minute RI starting from the second set: d = 0.4 (second set), 0.64 (third set), 1.03 (fourth set), and 1.3 (fifth set), for the 2-minute RI starting from the fourth set: d = 0.47 (fourth set) and 0.77 (fifth set), and for the 3-minute RI starting from the fourth set: d = 0.49 (fourth set) and 0.62 (fifth set).

Intraset Peak Power. Table 3 (males) and Table 4 (females) show the evolution of PP within the sets with each RI

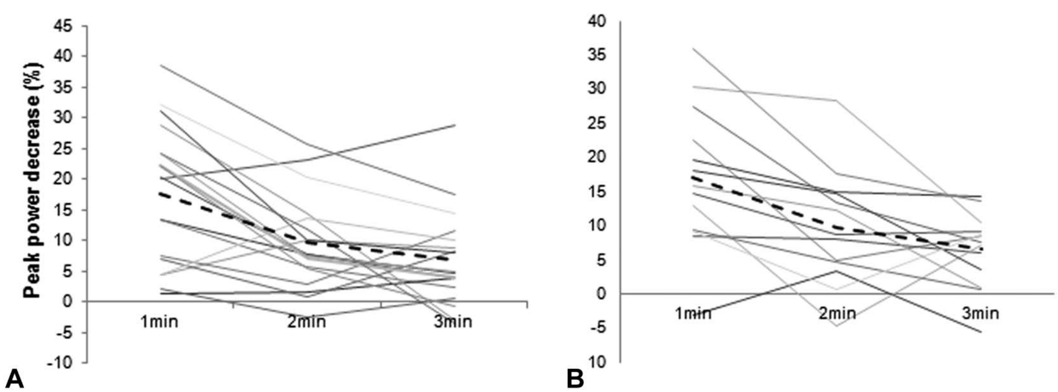

Figure 4. Individual responses of peak power (PP) decrease in males (A) and females (B) with the different rest interval used. Dashed line = sample average.

protocol. There were no differences in the total number of repetitions performed without a significant decrease in PP (compared with PP values of the first set of each set) neither in males (14, 15, and 12 repetitions for 1-, 2-, and 3-minute RIs, respectively) nor in females (12, 13, and 13 repetitions for 1-, 2-, and 3-minute RIs, respectively).

Nevertheless, when comparing the PP of the last repetition over the sets with the different RI protocols, the 1-minute RI showed a significantly higher decrease ($p \leq 0.05$) compared with the decreases for both 2-minute (d ranging from 0.80 to 0.94) and 3-minute RIs (d ranging from 1.15 to 1.3) in males (Table 5). In females, PP decreases for the 1-minute RI were higher than those obtained for the 2-minute RI (d ranging from 0.86 to 1.16) and for the 3-minute RI (d ranging from 1.15 to 1.85). However, no differences were found between 2- and 3-minute RI protocols.

The individual responses concerning PP decrease (i.e., % difference between the first and the fifth set) when using each RI are shown in Figures 4A, B (males and females). Despite subject's variability, the same tendency (sample average line) can be observed in both genders.

Discussion

The aim of this study was to test the influence of different RIs on power output performance when training for maximizing muscular power with 40% of 1RM in the bench press throw exercise. For that purpose, we compared 3 different RIs: 1, 2, and 3 minutes. The main findings were that when training with a load for developing muscular power in the bench press throw exercise, there were substantial differences in mechanical and physiological-perceptual variables when comparing the 1-minute RI with both 2- and 3-minute RIs. When using the 1-minute RI, results showed significant impairments in both, mechanical (e.g., MP and PP) and physiological-perceptual (e.g., [La$^+$], RPE) parameters, whereas no differences were found when comparing the 2- and 3-minute RIs.

Despite the between-gender differences in some outcomes, such as 1RM, MP and PP output, [La$^+$], or RPE, the influence of the different RIs used in this study has shown to be very similar for both genders. Therefore, throughout the discussion, there are no between-genders differentiations, and all explanations may be accepted for both males and females.

The results of this study agree with those reported by Abdessemed et al. (1) as 1-minute RI entailed higher power decreases compared with 3-minute RI. In this study, decreases in MP were observed for the 1-minute RI, started from the second set, whereas no significant decreases in MP were found in both 2- and 3-minute RIs, neither in males nor in females over the 5 sets. These significant decreases in MP were significantly higher than values showed when resting for 2 minutes (males) and 3 minutes (males and females) (Figure 2). When resting for 1 minute, PP decreases started after the second set in both males and females, whereas no reductions were observed until the third set (2-minute RI) and the fourth set (3-minute RI) in males, and until the fourth set (in both 2- and 3-minute RIs) in females (Figure 3). These significant impairments with a short (1 minute) RI were not found by Nibali et al. (26), who recently showed that 1-minute RI was enough to maintain PP output during light-loaded squat jumps, although this could be related to the lower training volume completed in that study (3 sets of 3 repetitions), which could hide larger power decreases using a short (1 minute) RI.

Although the number of repetitions within each set with a significant decrease in PP showed no difference between RIs neither in males nor in females, when comparing the PP in the last repetition over the sets with the PP of the last repetition in the first set, nevertheless, the 1-minute RI showed a higher percentage decrease than both 2- and 3-minute RIs (Table 5). Although no previous studies have analyzed the effect of different RIs on intraset power losses, Sánchez-Medina and Gonzalez-Badillo (2011) found greater velocity decreases when the number of repetitions performed in each set approached the maximum predicted number of repetitions for each load. Therefore, it seems that a short (1 minute) RI may affect power output production similar to increasing the number of repetitions performed in a set. Thus, although fatigue within sets seems to be similar despite the RI, a short (1 minute) RI does not allow for full recovery before the initiation of the subsequent set, leading to a significantly higher accumulated fatigue in the last repetitions of the sets.

From a physiological point of view, the greater decrease in power performance showed when resting 1 minute was accompanied by a significantly higher [La$^+$]. This increase in [La$^+$] reflects the greater use of the anaerobic system as a source of energy production, possibly leading to disturbances in several ions (e.g., H^+) and affecting muscle function (peak force and maximum muscle shortening velocity) as a result of lowered pH values (41). In addition, Ratamess et al. (32) showed higher increases in oxygen consumption and greater respiratory exchange ratio with short RIs (30 seconds and 1 minute), compared with 2-, 3-, or 5-minute RIs. These metabolic variables were highly correlated with fatigue rate during the bench press exercise. Concerning the influence of RI on neuromuscular fatigue, it could be hypothesized that 1-minute RI causes changes in the motor unit recruitment pattern, leading to contraction failures in fast-type motor units and, thus, affects power output performance (22). Indeed, it has been reported that power output decreases because of impaired intermuscular coordination and is expressed as changes in agonist-antagonist coactivation (27,36).

The slight performance impairments showed when resting for 2 minutes, is in line with the study of Scudese et al. (38) who found no significant differences in completed repetitions when using a 2-minute RI compared with either 3- or 5-minute RIs. In fact, Willardson and Burkett (44) showed no differences in strength gains when comparing 2- and 4-minute RI groups after 13 weeks of intervention. Most studies have evaluated the effect of different RI on either the acute (42,43) or chronic (40,44) strength responses taking volume completed as performance criterion. Although training with loads that maximize power output has been shown useful to develop power output and to increase dynamic athletic performance (45), researchers barely understand how the choice of power output decreases as a performance criterion can influence chronic power adaptations, and whether a short (2 minutes) RI in power training may affect chronic development of muscle power, strength gains, hypertrophy, or physiological variables (e.g., buffering changes).

The perceptual variables (RPE and DOMS scales) have been previously reported as sensitive tools to control training sessions' intensity (30,34). Accordingly, RPE values were significantly higher for the 1-minute RI compared with the 2-minute RI in males (25%) and the 3-minute RI in both males and females (38 and 26%, respectively). Scudese et al. (38) lately showed similar RPE results, whereas a 1-minute RI entailed higher values compared with a 3-minute RI, although in this study, differences between 1- and 2-minute RIs were not reported. However, the greater DOMS 24 experienced by males when resting for 1 and 2 minutes compared with the 3-minute RI, and for the DOMS 48 when comparing 1- vs. 3-minute RIs demonstrate that longer between-session times are required for full recovery when shorter RIs are used, although it should be checked how DOMS values ranging from 1.5 to 2.8 (in a 0–10 scale) may affect strength/power production during a training session since muscle pain can induce a reduction in the motor evoked potentials and H-reflex (19). High correlations have been reported between several variables associated with muscular hypertrophy (i.e., structural damage of sarcomeres, tearing of the Z-lines) and DOMS (4,8); therefore, it could be hypothesized that shorter RIs (such as 1 minute) even in power training sessions may lead to greater increases in muscle size.

The main limitations of this study include (a) the lack of neural measurements (i.e., surface electromyography) that could provide information about neural fatigue in the different RI conditions and (b) lack of measures of hormonal responses to different RIs. Furthermore, the different strength/power profiles found in our male sample might have obscured its possible influence on power output decreases over multiple sets. Based on our results, future studies should investigate the effect of different RIs on chronic power developments after continued power training exposure with shorter-than-traditional (2 minutes) RI and the effect on athletic populations with different strength/power profiles.

Practical Applications

When training for power development with a light load (40% of 1RM), a 2-minute RI makes the maintenance of performance possible during the training session to avoid higher metabolic requirements compared with a longer (3 minutes) RI. Consequently, excessively long RIs (i.e., 3–4 minutes) are not necessary and may detract from other conditioning priorities. Further research is warranted on the effects of whether continued exposure to power training with these short RIs may affect power output, strength gains, and hypertrophy in a different way than traditional power training with long RIs.

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