EFFECT OF DIFFERENT INTERREPETITION REST PERIODS ON BARBELL VELOCITY LOSS DURING THE BALLISTIC BENCH PRESS EXERCISE

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ABSTRACT

García-Ramos, A, Padial, P, Haff, GG, Argüelles-Cienfuegos, J, García-Ramos, M, Conde-Pipó, J, and Feriche, B. Effect of different interrepetition rest periods on barbell velocity loss during the ballistic bench press exercise. *J Strength Cond Res* 29(9): 2388–2396, 2015—This study investigated the effect of introducing different interrepetition rest (IRR) periods on the ability to sustain maximum bench press throw velocity with a range of loads commonly used to develop upper-body power. Thirty-four physically active collegiate men (age: 21.5 ± 2.8 years; body mass: 75.2 ± 7.2 kg; height: 176.9 ± 4.9 cm) were tested during 2 consecutive weeks. During the first week, the maximum dynamic strength (repetition maximum [RM]) in bench press exercise was determined (RM = 76.7 ± 13.2 kg). The following week, 3 testing sessions were conducted with 48 hours apart in random order. In each day of evaluation, only 1 load (30%RM, 40%RM, or 50%RM) was assessed in the bench press throw exercise. With each load, subjects performed 3 single sets of 15 repetitions (15-minute interset rest) with 3 different sets configurations: continuous repetitions (CR), 6 seconds of IRR (IRR6), and 12 seconds of IRR (IRR12). The decrease of peak velocity (PV) was significantly lower for IRR12 compared with CR and IRR6 at least since the repetition 4. No differences between CR and IRR6 protocols were found until the repetition 7 at 30%RM and 40%RM and until the repetition 5 at 50%RM. The decrease of PV during the CR protocol was virtually linear for the 3 loads analyzed ($r^2 > 0.99$); however, this linear relationship became weaker for IRR6 ($r^2 = 0.79$–0.95) and IRR12 ($r^2 = 0.35$–0.87). These results demonstrate that IRR periods allow increasing the number of repetitions before the onset of significant velocity losses.

KEY WORDS cluster training, fatigue, movement velocity

INTRODUCTION

Success in many athletic endeavors depends critically on the performer's ability to sustain the maximum power production possible for the duration of the event (10). Thus, it is important for athletes to develop high values of power output, and not least, to maintain their maximum power as long as possible. Although there are many studies investigating the maximum power output associated with a single repetition (1,20,29), there is much less information about the behavior of muscular power throughout the course of the multiple repetitions contained in a training set (3). This type of information is important because it may provide valuable feedback to sport practitioners about athlete's ability to sustain their maximal performance and consequently select the optimal range of repetitions to perform according to the performance deterioration that are willing to assume.

Inherent to every strength or power exercise is the decrease of movement velocity as fatigue increases (16,23,30). Given that movement velocity is a key factor in eliciting neuromuscular adaptations (26,30), fatigue must be avoided to maximize power training effects (2,9). A simple way of avoiding fatigue is performing few repetitions per set (2,5,17). For example, Baker and Newton (3) suggested that athletes attempting to develop maximal power should limit their repetitions to 2–5 when using loads of 35–45% of the 1 repetition maximum (RM) in the bench press throw and jump squat exercises. In this regard, rather than performing a fixed number of repetitions, some authors have proposed that a set must be terminated when power output or movement velocity drops below certain threshold, whenever the target is to improve maximal power production (23,30).

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29(9)/2388–2396

Journal of Strength and Conditioning Research

It is in this context when a novel training method known as cluster training comes into play. Cluster training is based on the introduction of short rest periods after every repetition (interrepetition rest [IRR]) or after a cluster of repetitions (intrarepetition rest). The goal of such rest periods is to minimize neuromuscular fatigue (25) and consequently improve the kinetic and kinematic variables compared with traditional continuous training (15). A superior mechanical stimulus of different cluster configurations has been already reported in several exercises, such as the bench press (25), parallel back squat (24), half back squat (12), power clean (18), clean pull (16), and jump squat (17), when compared with traditional continuous sets configurations. Therefore, considering the idea of executing repetitions until power output or movement velocity drops below certain threshold, the inclusion of rest periods between repetitions may considerably increase set's volume while maintaining optimal power output (9).

Most of the acute studies comparing cluster and traditional sets configurations have been conducted with moderate to heavy loads (≥70%RM) (9,16,18,24,25). There may be a need to explore the impact of cluster set configurations with lower loaded exercises such as those seen in power-based training. Given that upper-body power is maximized at lower loads (30–50%RM) (2,28), it seems necessary to study the effect of cluster set configurations with loads ≤50%RM. In this context, the main objective of this study was to examine the effect of introducing different IRR periods on the ability to sustain maximum bench press throw velocity, with a range of loads (30–50%RM) commonly used to develop upper-body power. These findings could provide useful information to sport practitioners about the optimal number of repetitions to perform based on the reduction of movement velocity that are willing to assume, and how this number of repetitions could be altered by implementing short rest periods between repetitions.

METHODS

Experimental Approach to the Problem

This study used a repeated-measures design to investigate the effect of introducing different IRR periods on the ability to maintain maximum bench press throw velocity with a range of loads commonly used to develop upper-body power. Subjects reported to the laboratory on 4 separate occasions during 2 consecutive weeks. During the first week, the maximum dynamic strength (RM) in bench press exercise was determined using a progressive loading test. The following week, 3 randomly assigned testing sessions were conducted using the bench press throw. To ensure an adequate recovery between testing sessions, a recovery duration of 48 hours was placed between each session. On each testing day, only 1 load (30%RM, 40%RM, or 50%RM) was lifted. With each load, subjects performed 3 single sets of 15 repetitions (15-minute interset rest) with 3 different randomly assigned set configurations: continuous repetitions (CR), 6 seconds of IRR (IRR6), and 12 seconds of IRR (IRR12). Peak velocity (PV) of each repetition was collected with a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain) to compare the 3 different protocols. Sessions were performed in the afternoons, at the same time of the day for each subject, and under similar environmental conditions (22–23° C and 60% humidity).

Subjects

Thirty-four physically active collegiate men (age: 21.5 ± 2.8 years [range: 20–33 years]; body mass: 75.2 ± 7.2 kg; height: 176.9 ± 4.9 cm; RM bench press: 76.7 ± 13.2 kg; relative RM bench press: 1.02 ± 0.16 $kg \cdot kg^{-1}$) volunteered to participate in this study. Selection criteria included having at least 6 months of experience in bench press training and not consuming drugs, medications, or dietary supplements, which influence physical performance. All subjects voluntarily read and signed an informed consent form in accordance with the

TABLE 1. Peak velocity values reached at the first repetition for each load and set configuration.*

Load (%RM)	Set configuration	PV ($m \cdot s^{-1}$)	Average PV ($m \cdot s^{-1}$)	ICC (95% CI)	CV (95% CI)
30	CR	2.271 ± 0.14	2.274 ± 0.14	0.97 (0.95–0.98)	1.5 (1.2–1.8)
	IRR6	2.264 ± 0.14			
	IRR12	2.288 ± 0.14			
40	CR	1.875 ± 0.15	1.872 ± 0.15	0.98 (0.97–0.99)	1.7 (1.4–1.9)
	IRR6	1.861 ± 0.15			
	IRR12	1.881 ± 0.15			
50	CR	1.530 ± 0.14	1.531 ± 0.14	0.97 (0.94–0.98)	2.3 (1.8–2.8)
	IRR6	1.525 ± 0.13			
	IRR12	1.538 ± 0.14			

*RM = repetition maximum; PV = peak velocity; ICC = intraclass correlation coefficient; CV = coefficient of variation; 95% CI = 95% confidence interval; CR = continuous repetition; IRR6 = 6-second interrepetition rest; IRR12 = 12-second interrepetition rest.

TABLE 2. Percent loss of repetition peak velocity within the different set configurations.*†

	30%RM			40%RM			50%RM		
Repetition	CR	IRR6	IRR12	CR	IRR6	IRR12	CR	IRR6	IRR12
1	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0	100 ± 0.0
2	98.9 ± 1.8	98.4 ± 1.9‡	99.6 ± 1.7§	98.2 ± 1.8	97.4 ± 1.9	98.4 ± 2.5	96.5 ± 2.3‡	96.9 ± 2.6	98.3 ± 2.5‖
3	98.0 ± 2.5	97.7 ± 2.1‡	99.2 ± 2.1§	97.0 ± 2.6	96.3 ± 2.6‡	97.5 ± 2.6§	93.9 ± 3.7‡	94.9 ± 3.2	96.0 ± 2.2‖
4	96.9 ± 2.5‡	97.0 ± 2.2‡	99.1 ± 2.1§‖	95.1 ± 2.7‡	95.3 ± 2.2‡	96.9 ± 3.0§‖	92.2 ± 3.8‡	92.9 ± 3.2‡	95.5 ± 2.7§‖
5	96.1 ± 2.6‡	96.5 ± 2.4‡	98.6 ± 2.3§‖	93.8 ± 3.0‡	94.1 ± 2.6‡	96.5 ± 2.9§‖	89.7 ± 4.3‡§	91.8 ± 4.3‡‖	94.5 ± 3.3§‖
6	95.3 ± 2.8‡	96.5 ± 2.4‡	98.4 ± 2.3§‖	92.0 ± 3.5‡	93.1 ± 2.8‡	96.4 ± 2.6§‖	87.4 ± 4.5‡§	89.9 ± 4.1‡‖	94.3 ± 3.3§‖
7	94.2 ± 3.1‡§	95.8 ± 3.0‡‖	98.4 ± 2.3§‖	90.2 ± 3.3‡§	92.1 ± 3.1‡‖	96.1 ± 2.7§‖	85.4 ± 4.4‡§	89.0 ± 4.2‡‖	93.3 ± 3.7§‖
8	93.2 ± 2.8‡§	95.8 ± 2.9‡‖	98.3 ± 2.3§‖	88.4 ± 3.5‡§	91.8 ± 3.2‡‖	96.5 ± 2.3§‖	81.7 ± 5.0‡§	88.1 ± 4.9‡‖	93.1 ± 4.0§‖
9	92.0 ± 3.1‡§	95.6 ± 3.3‡‖	98.8 ± 2.6§‖	87.0 ± 3.6‡§	91.4 ± 3.1‡‖	95.4 ± 3.4§‖	78.6 ± 6.1‡§	86.9 ± 6.1‡‖	92.4 ± 4.0§‖
10	91.3 ± 3.0‡§	95.4 ± 3.4‡‖	98.2 ± 3.3§‖	84.5 ± 4.7‡§	90.8 ± 3.1‡‖	95.9 ± 2.6§‖	77.1 ± 6.3‡§	86.1 ± 4.9‡‖	91.8 ± 4.5§‖
11	90.2 ± 2.9‡§	95.2 ± 3.1‡‖	98.6 ± 2.9§‖	83.1 ± 3.6‡§	90.2 ± 3.9‡‖	95.4 ± 3.0§‖	73.7 ± 6.6‡§	85.5 ± 6.7‡‖	91.6 ± 5.2§‖
12	89.1 ± 3.1‡§	94.6 ± 3.0‡‖	98.3 ± 2.6§‖	81.1 ± 4.7‡§	90.3 ± 3.1‡‖	94.8 ± 3.4§‖	70.8 ± 7.5‡§	84.7 ± 6.4‡‖	91.7 ± 4.6§‖
13	88.1 ± 3.6‡§	94.8 ± 3.3‡‖	98.4 ± 2.7§‖	80.0 ± 4.1‡§	89.8 ± 3.9‡‖	95.1 ± 3.2§‖	69.2 ± 6.1‡§	83.8 ± 6.2‡‖	90.8 ± 4.8§‖
14	87.0 ± 3.5‡§	94.8 ± 3.1‡‖	98.6 ± 2.9§‖	78.0 ± 4.6‡§	89.4 ± 3.8‡‖	95.0 ± 3.3§‖	65.0 ± 7.9‡§	83.2 ± 7.3‡‖	90.9 ± 4.9§‖
15	86.9 ± 3.3‡§	95.3 ± 3.4‡‖	99.0 ± 3.6§‖	76.0 ± 5.8‡§	89.3 ± 3.7‡‖	95.5 ± 3.1§‖	61.8 ± 8.2‡§	81.5 ± 8.5‡‖	91.1 ± 5.5§‖

*Data are given as mean ± *SD*.
†RM = repetition maximum; CR = continuous repetition; IRR6 = 6-second interrepetition rest; IRR12 = 12-second interrepetition rest.
‡Significantly different from IRR12 ($p \leq 0.05$).
§Significantly different from IRR6.
‖Significantly different from CR.

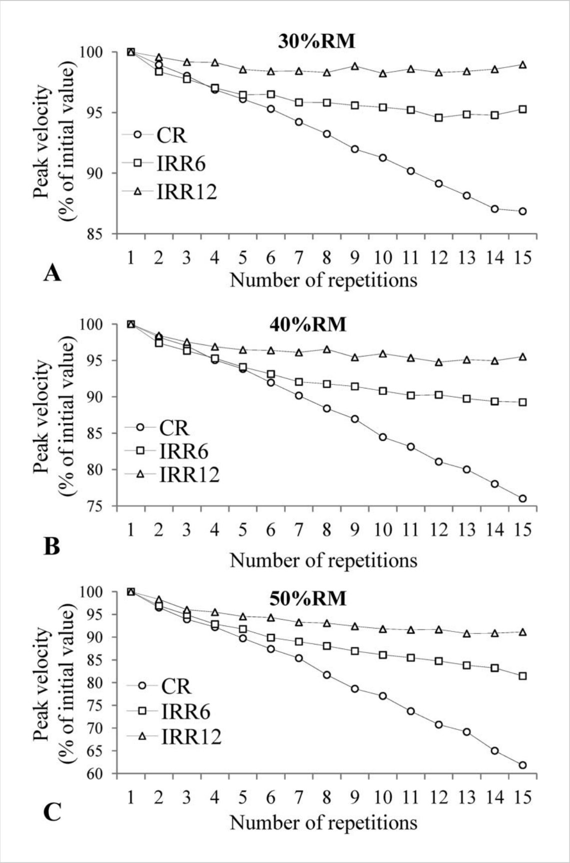

Figure 1. Peak velocity changes produced during the course of submaximal single sets performed at 30%RM (A), 40%RM (B), and 50%RM (C). CR = continuous repetition protocol; IRR6 = 6 seconds of interrepetition rest protocol; IRR12 = 12 seconds of interrepetition rest protocol; RM = repetition maximum. *SD*s and significance have been omitted for clarity but are retained in Table 2.

University of Granada Institutional Review Board and The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Repetition Maximum Determination (Session 1)

Subjects came to the testing having refrained from strenuous exercise for a minimum of 48 hours. As soon as they arrived, their height (Seca 202; Seca Ltd., Hamburg, Germany) and body mass (Tanita BC 418 segmental, Tanita corporation, Tokyo, Japan) were assessed. Before the commencement of the RM determination, subjects elected the grip width that was the most comfortable, which was measured and kept constant throughout all testing sessions. The warm-up consisted of joint mobility, dynamic stretching, and 2 sets of 5 repetitions with 20 and 30 kg, respectively. Subjects then completed a progressive loading test to determine bench press RM. Initial load was set at 40 kg for all subjects and was progressively increasing in steps of 10 to 1 kg, so that RM could be determined with a high level of precision. The heaviest load that each subject could properly lift was considered to be his RM. Subjects performed 1–2 repetitions per load, and the recovery time between attempts was at least 5 minutes.

Subjects started the movement with their elbows fully extended and with their self-selected grip of the bar. Then, the barbell was lowered in a continuous motion of 1.5 seconds until it was positioned 1–2 cm above their intermammary line, and they were required to maintain this position for 1 second (velocity = 0 $m \cdot s^{-1}$). From that position, every subject was instructed to perform a purely concentric action to regain the initial position. The duration of eccentric and isometric phases was administered by auditory feedback through an ad hoc audio file, whereas the concentric phase was always performed explosively at the maximum possible speed.

Interrepetition Rest Protocols (Sessions 2–4)

In the second week, subjects undertook 3 randomly assigned testing sessions with 48 hours apart. Only 1 load (30%RM, 40%RM, or 50%RM) was tested each day of evaluation with which subjects performed 3 single sets of 15 repetitions. A recovery time of 15 minutes was implemented between sets. This basic design was adapted from previously published research examining cluster sets (16).

The 3 sets performed during each testing session only differed in the recovery time between repetitions:

- CR: No rest between repetitions.
- IRR6: 6 seconds of rest between each repetition.
- IRR12: 12 seconds of rest between each repetition.

The order of execution of the different intensities (30%RM, 40%RM, and 50%RM) and the set configurations (CR, IRR6, and IRR12) were randomized in accordance with the cluster set study design presented by Haff et al. (16).

The exercise performed during sessions 2–4 was the bench press throw. The technique of execution was similar to the one explained above, with the only difference that subjects accelerated the bar during the entire range of movement with the intention of throwing it as high as possible. The same ad hoc audio file was used to determine the duration of the eccentric and isometric phases. The rest between repetitions was monitored with a stopwatch, which was started at the moment that subject released the bar.

All tests (sessions 1–4) were performed in a Smith machine (Technogym, Barcelona, Spain) in which the barbell was attached to both ends, with linear bearings on 2 vertical bars allowing only vertical movements. A dynamic measurement system (T-Force System; Ergotech) validated by Sánchez-Medina and González-Badillo (30) was fixed perpendicularly to the bar with a tether to record directly its vertical instantaneous velocity at a frequency of 1,000 Hz. A complete description of this system is provided elsewhere (30). Peak velocity was defined as the maximum instantaneous velocity attained during the concentric phase of each repetition.

Statistical Analyses

Data are presented as mean ± *SD* values. Before any statistical analysis, the normal distribution of the data

TABLE 3. Relationship between the number of repetitions performed and relative peak velocity loss using simple linear regression and quadratic regression models.*

Protocol	Load (%RM)	Model	Equation	Adj. r^2	SE_E	F statistics
CR	30	Linear	$Y = -0.971x + 100.93$	0.998	0.196	6870.4†
		Quadratic	$Y = 0.002x^2 - 1.001x + 101.01$	0.998	0.201	3262.7†
	40	Linear	$Y = -1.714x + 102.00$	0.999	0.292	9624.5†
		Quadratic	$Y = -0.008x^2 - 1.586x + 101.64$	0.999	0.265	5841.9†
	50	Linear	$Y = -2.648x + 102.72$	0.996	0.717	3817.2†
		Quadratic	$Y = -0.026x^2 - 2.230x + 101.54$	0.998	0.568	3044.0†
IRR6	30	Linear	$Y = -0.304x + 98.66$	0.794	0.685	55.1†
		Quadratic	$Y = 0.034x^2 - 0.855x + 100.22$	0.956	0.318	151.9†
	40	Linear	$Y = -0.690x + 98.27$	0.897	1.044	122.4†
		Quadratic	$Y = 0.055x^2 - 1.573x + 100.77$	0.987	0.364	551.4†
	50	Linear	$Y = -1.174x + 98.40$	0.952	1.174	280.0†
		Quadratic	$Y = 0.058x^2 - 2.097x + 101.02$	0.988	0.591	571.5†
IRR12	30	Linear	$Y = -0.072x + 99.34$	0.347	0.417	8.4‡
		Quadratic	$Y = 0.021x^2 - 0.401x + 100.27$	0.838	0.208	37.2†
	40	Linear	$Y = -0.277x + 98.58$	0.747	0.712	42.4†
		Quadratic	$Y = 0.032x^2 - 0.786x + 100.02$	0.899	0.449	63.6†
	50	Linear	$Y = -0.581x + 98.34$	0.867	1.013	92.2†
		Quadratic	$Y = 0.052x^2 - 1.412x + 100.70$	0.976	0.430	286.0†

*Y = peak velocity value relative to the first repetition; x = number of repetition; CR = continuous repetition; IRR6 = 6-second interrepetition rest; IRR12 = 12-second interrepetition rest; adj. r^2 = adjusted Pearson's multivariate coefficient of determination; SE_E = standard error of the estimate (%).

†ANOVA significance; $p < 0.001$.

‡ANOVA significance; $p = 0.05$.

(Shapiro-Wilk test) and the homogeneity of variances (Levene's test) were confirmed ($p \leq 0.05$). The magnitude of the differences in the PV values reached at the first repetition among the 3 different set configurations (CR, IRR6, and IRR12) for each of the intensities analyzed (30%RM, 40%RM, and 50%RM) was expressed as a standardized mean difference (Cohen's d effect size [ES]). The criteria to interpret the magnitude of the ES were as follows: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and >2 = very large (21). The average PV value of the 3 set configurations obtained at the first repetition (before the application of the independent variable and rest between repetitions) for each load was settled down as the criteria to compare PV losses between protocols. One-way analysis of variance with repeated measures was used to examine differences in PV losses between protocols for each load. When a significant F value was achieved, pairwise differences between mean values were identified using Bonferroni post hoc procedures. The percentages of PV loss produced during the course of the different sets performed were predicted through simple linear regression and quadratic regression models. The adjusted Pearson's multivariate coefficient of determination (adj. r^2), the standard error of the estimate (SE_E), and the model equations are provided. All statistical tests were performed using the software package SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA). Significance was set at $p \leq 0.05$.

RESULTS

The descriptive data of the PV value reached at the first repetition for each set configuration are provided in Table 1. The ES for all comparisons within the same load was trivial (<0.2). In addition, the reproducibility of PV at the first repetition was very high for all the intensities analyzed (intraclass correlation coefficient >0.95 and coefficient of variation <2.5%) (Table 1).

Table 2 displays the percentages of PV loss for each set configuration at the different intensities analyzed. The decrease of PV was significantly lower for IRR12 in comparison with CR and IRR6 at least since the repetition 4. No differences between CR and IRR6 protocols were found until the repetition 7 at 30%RM and 40%RM and until the repetition 5 at 50% RM. A graphical representation of PV behavior during the course of the different sets performed is depicted in Figure 1.

The decrease of PV during the CR protocol was virtually linear for the 3 loads analyzed ($r^2 > 0.99$); however, this linear relationship became weaker when rest between repetitions was implemented (IRR6: $r^2 = 0.79–0.95$; IRR12: $r^2 = 0.35–0.87$) (Table 3). Indeed, the F statistic was always higher using the simple linear regression model in the CR protocol, whereas for IRR6 and IRR12 protocols the F statistic was higher using the quadratic regression model.

Finally, Table 4 shows the repetition number at which the highest PV value is achieved for each set performed. Most of

Table 4. Repetition number at which the highest peak velocity value is achieved.*†

	30%RM			40%RM			50%RM		
Repetition	CR	IRR6	IRR12	CR	IRR6	IRR12	CR	IRR6	IRR12
1	24	20	12	28	27	22	32	25	26
2	6	6	2	2	4	6	1	5	4
3	2	2	3	4	1	1	1	3	
4	2	1	3		1	1		1	1
5		1							1
6						1			
7			3						
8						1			
9		2				1			
10		1	2						
11			3						
12									
13		1	4			1			1
14					1				
15			2						1
n	34	34	34	34	34	34	34	34	34

*RM = repetition maximum; CR = continuous repetition protocol; IRR6 = 6-second interrepetition rest protocol; IRR12 = 12-second interrepetition rest protocol; *n* = total number of samples.

†The numbers indicate the amount of subjects that achieved their fastest lifting at each repetition.

the subjects reached their fastest lifting at the first repetition: 70.6% at 30%RM, 82.4% at 40%RM, and 94.1% at 50%RM for the CR protocol; 58.8% at 30%RM, 79.4% at 40%RM, and 73.5% at 50%RM for the IRR6 protocol; and 35.3% at 30%RM, 64.7% at 40%RM, and 76.5% at 50%RM for the IRR12 protocol.

Discussion

The primary purpose of this study was to provide baseline data on the sustainability of maximum bench press throw velocity during a multiple repetitions protocol with a range of loads commonly used during upper-body power training. As has been previously reported (18,25), our results showed a near linear decrease in movement velocity ($r^2 > 0.99$) when repetitions were performed in a continuous manner (CR protocol). When heavier loads are applied, there is an increased degree of reduction in the movement velocity across the set which is partially obviated by the implementation of the cluster set structure (see linear regression slopes in Table 3). Specifically, when short rest periods were introduced between repetitions (IRR6 and IRR12 protocols), the linear behavior of velocity loss was altered. These results suggest that the inclusion of IRR periods may stimulate fatigue mechanisms in a different way than traditional continuous protocols, allowing increase in the number of repetitions performed at optimal velocities.

Muscle fatigue is defined as the decline in ability of a muscle to generate force (6,11). Multiple mechanisms can be responsible for the onset of muscle fatigue, being the prevailing mechanism specific to the task that is being performed (4). Broadly, the strategy commonly followed is to determine whether the mechanism responsible for fatigue is located in the exercising muscles (contractile fatigue) or in the nervous system (neural fatigue) (4,6). However, the nervous system and muscle are closely related, and thus it is very difficult to determine from where fatigue comes (4). When the target is to develop muscular power it is widely recommended to perform low repetitions per set and ensuring appropriate rest periods to minimize fatigue and thereby maximize training effects (3,8). Baker and Newton (2) indicated that power output markedly decreases after 3 repetitions when using resistances that maximize power output (around 45–50% RM bench press) during the bench press throw exercise. Because of the short time under tension that occurs in only 3 repetitions, the metabolic accumulation could be negligible, and therefore, the neural fatigue would be the main responsible of this performance impairment.

One of the variables that significantly influence fatigue mechanisms is the continuous or intermittent nature of the task performed (4). In fact, cluster training has already been shown to diminish lactate buildup in comparison with traditional continuous training (9,13,22). Metabolic stress is the result of the accumulation of metabolites (particularly lactate, Pi and H^+) and could be beneficial to promote hypertrophic adaptations (31). However, it should be avoided when the target is developing muscular power (9,13,17). In concordance, the typical hypertrophy-oriented training routines (multiple sets of 6–12 repetitions, moderate intensities, and short interset rest intervals) are designed to induce a great metabolic stress in detriment of higher training intensities (31). In contrast, during power-oriented training (few repetitions at maximum possible speed), the energy provision is mainly derived from the phosphagen system and thus should result in minimal metabolic buildup (31). Therefore, metabolic fatigue does not seem to be the main cause of the reduction in movement velocity that occurs during the early repetitions of a training set.

A striking result was the weak differences observed in movement velocity between the CR and IRR6 protocols during the early repetitions performed. No more than 1% of differences in velocity loss were found until the repetition 6 at 30%RM (CR = 95.3% and IRR6 = 96.5%) and 40%RM (CR = 92.0% and IRR6 = 93.1%) and until the repetition 5 at 50%RM (CR = 89.7% and IRR6 = 91.8%). As may be seen in Figure 1, in consonance with the CR protocol, the IRR6 protocol showed a near linear decrease of PV during the early repetitions performed (approximately until the repetition 5 at 30%RM and 40%RM and until the repetition 4 at 50%RM). However, from this point, whereas PV continuous decreasing linearly in the CR protocol, PV seems to remain more constant during the IRR6 protocol. Indeed, although the decrease of PV during the first 5 repetitions was very similar for both set configurations (CR vs. IRR6: 3.9% vs. 3.5% at 30%RM; 6.2% vs. 5.9% at 40%RM; 10.3% vs. 8.2% at 50%RM), the decrease of PV between the fifth and the fifteenth repetition was much more pronounced for the CR protocol (CR vs. IRR6: 9.2% vs. 1.2% at 30%RM; 17.8% vs. 4.8% at 40%RM; 27.9% vs. 10.3% at 50%RM) (Table 2). These results suggest that IRR6 are not enough to mitigate the fatigue mechanisms that appear in the earliest repetitions, but with increasing number of repetitions metabolic fatigue becomes more important (30), and in this case the IRR6 protocol allows the development of greater velocities.

To the best of our knowledge, the study of Hansen et al. (17) is the only study that has analyzed the acute effects of different cluster or IRR interval configurations on ballistic exercises performance with low relative intensities (<50%RM). This study examined the effect of 3 different cluster configurations (6 × 1 repetition with 12-second rest, 3 × 2 repetitions with 30-second rest, and 2 × 3 repetitions with 60-second rest) on the power output recorded during the jump squat with an absolute load of 40 kg (≈20%RM). They reported a significant decrease in power output from repetitions 4–5 for the traditional condition compared with the 3 different cluster configurations. Specifically, significant differences were found since the repetition 4 for the IRR set (12 seconds of rest between each repetition). Similar results were obtained in this study for the IRR12 protocol. In comparison with the traditional CR, in our study, movement velocity was significantly higher after repetition 4 at 30%RM and 40%RM and after repetition 2 at 50%RM. A possible advantage of this study in comparison with Hansen et al. (17) is that in our study all the subjects were tested with the same relative intensity (%RM). Because the decrease in movement velocity or power output is affected by the relative intensity (%RM), as has been shown in this and previous studies (23), it seems adequate that in this kind of studies all subjects are tested with the same relative intensity to truly understand the impact of varying the IRR interval.

The emergence of devices as linear position transducer (19) or linear velocity transducer (30), which provide feedback in real time on power output and movement velocity developed in every repetition, opens the possibility of creating new training methodologies in which movement velocity can be used as a measure to control resistance training intensity (14). In this context, Sánchez-Medina and González-Badillo (30) found high correlations between mechanical (velocity loss) and metabolic (lactate and ammonia) measures of fatigue supporting the validity of using velocity loss as an objective measure to quantify neuromuscular fatigue during resistance training. Unfortunately, there are no studies dealing to investigate the physiological adaptations after a resistance training period in which different velocity losses are allowed. Some studies have settled different arbitrary points to determine when a training set must be terminated (23,26), but the physiological reason for this decision remains unclear. Therefore, it would be ideal that future studies examine the physiological response of the organism to different percentages of velocity loss. Until then, it seems that no more than 10–15% should be permissible when the target is to stimulate primarily muscle shortening velocity and maximum power.

Multiple criteria can be used to monitor velocity loss to decide when the set must be terminated. Velocity loss can be reported relative to the first repetition (30), the average of the first 2 repetitions (23), or even the best repetition performed within the set. A handicap of using the first repetition is that its bad execution can contaminate the entire process. For example, if the coach decides to stop the set when a 10% of velocity is lost regarding the first repetition, and for any reason the velocity reached in the first repetition is only a 80% of the maximum possible, the athlete will be able to perform the following repetitions with greater velocities (e.g., a 117% of first repetition's velocity), and worse is that the number of repetitions would be counterproductively increased because athletes will be instructed to perform repetitions until they loss a 10% of their 80% maximum velocity. The best repetition performed within a set should be considered as the reference to avoid this issue.

As shown in Table 4, the fastest repetition within a set was mostly attained at the first repetition. This fact was especially true for the most fatiguing protocols (the ones with higher loads and lower IRR periods) because of the unlikely increase of movement velocity in successive repetitions as fatigue increases. These findings contradict previous studies that have recorded the highest power output at the third repetition in the bench press throw exercise (3). The average

PV value of the 3 set configurations obtained at the first repetition for each load was the criterion used to compare the 3 different protocols. Providing a common reference value for each load was necessary to compare the different set configurations, or otherwise a same absolute value of PV during successive repetitions would imply different percentages of velocity loss for each protocol.

The bench press throw is probably the most recommended exercise to develop upper-body muscular power (28). There are 2 main reasons why sport practitioners choose this exercise: (a) the continuous acceleration throughout the entire range of motion that promotes higher values of velocity, power, force, and muscle activation in comparison with similar traditional resistance training exercises (e.g., bench press) (27) and (b) the greatest similarity with the athletic competition movement (8). In addition, the range of loads used in this study (30–50%RM) is the ones that have shown to maximize power output in the assessed exercise (2,28) and thus have been assiduously recommended when the target is to develop upper-body muscular power (7). Because adaptations are specific to the resistances used in training, the load that maximizes power output provides the best stimulus to elicit the physiological changes necessary to increase maximal power output (7). Therefore, the results presented in this study may have a valuable significance in the real context of upper-body power training.

PRACTICAL APPLICATIONS

The continuous or intermittent nature of the task performed is one of the main variables that influence fatigue mechanisms. Indeed, our results showed that the inclusion of IRR periods alters the traditional linear behavior of velocity loss widely described during CR protocols. In comparison with a traditional continuous protocol, the inclusion of IRR periods of just 6 seconds is not adequate to induce performance gains within the first repetitions of a training set. Therefore, longer rest intervals may be required to minimize the fatigue mechanisms that prevail during the early repetitions associated with a multirepetition set structure. Based on this study, an IRR of 12 seconds seems to produce more favorable responses when compared with traditional or shorter IRR intervals. In fact, compared with the first repetition of the training set, there was a <10% decline in movement velocity across the 15 repetition performed in the tested set when a 12-second IRR interval was used. If higher loads were to be used in the set, it is likely that a longer (>12 seconds) IRR interval may be needed to maintain movement velocity across a set of 15 repetitions. Based on these findings, strength and conditioning professionals can adapt training interventions through targeted strategies that manipulate the IRR interval to optimize the movement velocity across various set structures when performing ballistic exercises, such as the bench press throw. Additionally, these results may be used as reference values with which to compare the ability of other sport practitioners to sustain maximum bench press throw velocity at the same relative intensities.

ACKNOWLEDGMENTS

The authors thank all the students who selflessly participated in the study. This study was funded in part by a predoctoral grant (FPU12/00360) awarded to one of the authors (A.G.R.) by the Spanish Ministry of Education.

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