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THE EFFECT OF DIFFERENT INTER-REPETITION REST PERIODS ON THE SUSTAINABILITY OF BENCH AND LEG PRESS REPETITION

VPLIV TRAJANJA ODMORA MED PONOVITVAMI PRI POTISKU UTEŽI IZPRED PRSI IN DVIGOVANU IZ POLČEPA

ABSTRACT

There is a lack of studies using inter-repetition rest periods in the upper and lower muscle groups on the sustainability of repetition. The purpose of this study was to compare the effect of three different inter-repetition rest periods on the sustainability of bench and leg press repetition over four consecutive sets that were performed with 75% of one repetition maximum. Twenty resistance-trained college-age men participated in four testing sessions which involved the determination of one repetition maximum (first session) and the performance of four sets of bench presses and leg presses to exhaustion at 75% of 1RM load with inter-repetition rest periods of 0, 2 and 4 seconds (during the next three testing sessions). A zero-second inter-repetition rest period resulted in significantly greater sustainability of bench press and leg press repetitions compared to 2 and 4 second inter-repetition rest periods (BP: 9.27±2.15, 7.78±1.27, 7.78±1.3, LP: 9.87±1.49, 8.77±1.02, 8.96±1.46, respectively, $p<0.05$). The results demonstrate that increasing inter-repetition rest periods in resistance training reduces the sustainability of repetition.

Key words: resistance training, inter-repetition rest, repetition, sustainability of repetition

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IZVLEČEK

Vpliv trajanja odmora med ponovitvami na njihovo vzdržljivost med potiskom uteži s prsi in dvigom iz polčepa ni raziskan. Namen te raziskave je bil primerjati vpliv treh različno dolgih počitkov med ponovitvami (IRR) na vzdržljivost pri ponavljanju dvigov uteži na klopci in počepov na napravi, in sicer v štirih sklopih vaj, ki so bile izvedene ob 75 % maksimalne vrednosti ene ponovitve (1RM). V štirih sklopih testiranja vadbe z uporom je sodelovalo dvajset visokošolskih študentov, vaje pa so obsegale določitev maksimalne vrednosti ene ponovitve (1RM) (1. vaja) ter izvedbo štirih sklopov dvigov uteži na klopci (BP) in počepov na napravi (LP) do izčrpanosti pri 75 % 1RM obremenitve z 0, 2 in 4 sekundami IRR (2., 3. in 4. vaja). Ponovitve BP in LP do izčrpanosti od prvega do četrtega sklopa vaj so bile značilno višje pri IRR 0 sekund kot pri IRR 2 in 4 sekunde ($p< 0.05$). Rezultati so pokazali, da povečevanje IRR pri vadbi z uporom znižuje vzdržljivost ponavljanja (SR).

Ključne besede: vadba z uporom, počitek med ponovitvami, ponavljanje, vzdržljivost pri ponavljanju

INTRODUCTION

Resistance training programmes can be designed to emphasise maximal muscular strength, power, hypertrophy and muscular endurance (Kraemer, Adam, & Fleck, 2002; ACSM, 2002). While designing a resistance training programme, several variables must be considered such as the intensity, volume, frequency and sustainability of repetition (SR), along with velocity and inter-set rests (ISR) (ACSM, 2002). All of these variables can be manipulated to meet specific training goals and address individual needs (ACSM, 2010). The length of inter-repetition rests (IRR) or inter-set rests (ISR) is an important variable when designing a resistance exercise programme. Several recent reviews of inter-set rest intervals indicate that longer rest periods allow a greater volume of exercise (sets × resistance × repetitions) and that specific resistance training adaptations such as muscular strength, hypertrophy and power depend on the ability to maintain a specific number of repetitions for consecutive sets of a given exercise (Willardson, 2006; Salles, Simao, Miranda, Novaes, Lemos, & Willardson, 2009).

Many studies established the concept that performing fewer repetitions at a higher percentage of one repetition maximum (1RM) is perceived to be harder than performing greater repetitions at a lower percentage of 1RM (Day, McGuigan, Brice, & Foster, 2004; Lagally, Robertson, Gallagher, Gearhart, & Goss, 2002; Lagally, 2002). The many prescriptive variables may include: exercise order, rest intervals between sets and exercises, frequency, velocity of movement, number of sets and repetitions, and load or intensity. All of these variables can be changed to suit specific training goals and individual needs (Kraemer et al., 2002, ACSM, 2002, Baechle, Earle, & Wathan, 2000, Weiss, 1991).

Resting between sets and exercises has been shown to affect the metabolic (Haltom, Kraemer, Sloan, Hebert, Frank, & Trynieckil, 1999, Kraemer, Noble, Clark, & Culver, 1987) hormonal (Kraemer, et al., 1990; 1991, Buresh, Berg, & French, 2009, Rahimi, Qaderi, Faraji, & Boroujerdi, 2010; Rahimi Rohanib, & Ebrahimi, 2011) and neural (Kraemer, 1992) responses to an acute bout of resistance exercise, as well as the performance of subsequent sets (Kraemer, 1997) and muscular strength improvements (Pricivero, Lephart, & Karunakara, 1997; Robinson, 1995). A suitable recovery period is required to sustain consistent repetitions. The effects of a predetermined time period between sets on training volume as measured by repetitions to exhaustion Kraemer (1997) 3 sets × 10RM with 1 and 3 minute rests; Todd and co-workers (2001) 3 sets × 60% 1RM and 90% 1RM with 1, 2, 3, 4 and 5 minute rests; Richmond and Godard (2004) 2 sets × 75% 1RM with 1, 3 and 5 minute rests; Rahimi (2005) 4 sets × 85% 1RM with 1,2 and 5 minute rests; Willardson and Burkett (2005) 4 sets × 8RM with 1, 2 and 5 minute rests; Arazi and Rahimi (2011) 3 sets × 75% 1RM with a 3 minute rest period; a 1:3 work: rest ratio (1:3 W/R) and achieving a post-exercise heart rate of 60% age-predicted maximum (60% Post-HR) indicated that, when training with submaximal loads between 50 and 90% of 1RM, long rest periods of 3 to 5 minutes between sets allowed for more total repetitions to be completed during a workout. The aforementioned studies establish the concept that performing fewer repetitions at a lower ISR is regarded as being harder than performing greater repetitions at a higher ISR. However, one study found that different rest conditions were equally effective methods of recovery during sets of resistance training to exhaustion (Larson & Potteiger, 1997). If fatigue decreases the power output during power training, based on previous findings (Lawton, Cronin, & Lindsell, 2006) IRR may be a rational approach to increasing SR when training for power.

A few studies have investigated the effects of IRR during resistance training. Bryd and co-workers (1988) reported significantly increased work output after training with a one-second IRR loading scheme (30%) compared with continuous (25%) and two-second IRR (23%) loading schemes.

Lawton and co-workers (2004) compared the effect of continuous repetition (CR) training and intra-set rest (ISR) training on bench press strength and power in 26 male junior elite basketball and soccer players. They reported that the CR group significantly increased their 6RM strength (9.7%) compared with the ISR group (4.9%). Bench press training involving four sets of continuous repetition elicited a bigger improvement in bench press strength than eight sets of three repetitions at the same percentage load of their 6RM. Recently, IRR have become interesting to individuals concerned with the development of muscular abilities. Lawton and co-workers (2006) determined changes in weight training repetition power output as a consequence of inter-repetition rest intervals. Twenty-six elite junior male athletes performed bench presses using a six repetition maximum (6RM) load: 6 × 1 repetition with 20-second rest periods between every repetition (Singles); 3×2 repetitions with 50 seconds between every pair of repetitions (Doubles); or 2×3 repetitions with 100 seconds of rest between every three repetitions (Triples). They concluded that utilising IRR intervals enables further repetition and greater total power output compared to traditional loading parameters. Hardee and co-workers (2012) found increasing IRR in six power clean trainings decreases the perception of effort and is inversely related to the rate of fatigue. Ten resistance-trained males performed 3×6 repetitions at 80% of 1RM with 0 (P0), 20 (P20), or 40 s (P40) of IRR. Fatigue during all three conditions was indicated by a significant decrease in power of 9.0% (P0), 3.0% (P20) and 2.1% (P40), respectively. The significant difference in the rate of power decrease in P40 indicates less fatigue in comparison to P0 and P20. P40 resulted in a significantly lower rating of perceived exertion (RPE) compared to P0 and P20 (7.43 ± 0.34, 6.46 ± 0.47, and 5.30 ± 0.55, respectively). RPE increased significantly ($p < 0.01$) within each set (5.26 ± 0.37, 6.46 ± 0.44, and 7.46 ± 0.53; sets 1, 2 and 3, respectively). Therefore, to our knowledge, the impact of 0, 2 and 4 second IRR intervals on the volume of upper and lower muscle groups multiple exercises completed with a 75% 1RM load has not been reported, and resistance-trained athletes such as bodybuilders must perform exercises at maximal or near maximal intensities with repeated efforts in order to improve their muscular hypertrophy and/or strength (Rahimi, 2005). Although the aforesaid studies examined the effect of IRR on RPE, power, velocity and displacement during a single set exercise protocol, noting that neither study analysed SR during their investigation, it may be speculated that IRR may manifest changes to SR due to the attenuation of fatigue. Interestingly, the effects of IRR on SR are still unknown, but there seems to be an association between RPE, repetition, fatigue, and power output. Therefore, the purpose of this investigation was to compare the effects of different inter-repetition rest intervals on the sustainability of bench and leg press repetitions as measured by repetition to exhaustion over four sets with 75% of a 1RM load.

METHOD

Participants

The sample consisted of 20 healthy college-age men (age 21.50±2.43 years; height 174.65±5.17 cm; body weight 70.75±8.63 kg; body fat 14.47±2.81%) who volunteered to participate in the study. The subjects had at least six months of recreational resistance training experience. They had not undertaken resistance training for more than 3 days a week.

Instrument and procedure

The subjects were informed of the purpose, procedures and possibility of withdrawal from the study at any time without prejudice. They were asked to refrain from strenuous activity and maintain normal dietary habits between each session. They then completed a medical history questionnaire and signed a written informed consent approved by the Institutional Review Board at Guilan University.

Exercise programme

All subjects participated in four sessions with a 72-hour recovery period between each session. The subjects were required to warm up before each testing session, with the warm-up involving the performing of upper and lower body flexibility exercises and two sets of 12 repetitions at 40% of 1RM. The first session consisted of the documentation and determination of 1RM for BP and LP. During the next three testing sessions, after a warm-up the subjects completed four sets at 75% of 1RM with 0, 2 or 4 seconds of inter-repetition rest and 3 minutes of rest between the sets.

Assessment procedures

All subjects reported to the Laboratory at Guilan University for the first session after refraining from strenuous exercise for a minimum of 72 hours. In the first session, the subjects' height, weight and body fat were measured. 3-5 BP and LP were made to determine the 1RM in accordance with Kraemer and Fry (1955) with 5 minutes' rest between them. The rest between sets was timed using a hand-held stopwatch. All subjects received standard instructions on the exercise technique prior to testing which was also monitored and corrected as needed. To ensure a similar velocity of each repetition, a metronome was used consisting of a one-second concentric phase and a two-second eccentric phase.

After measuring the 1RM in the BP and LP, the 75% 1RM loads were applied in the testing sessions. During the next three testing sessions, four consecutive sets of BP and LP were performed to voluntary exhaustion at 75% of 1RM with 0 (second session), 2 (third session) and 4 (fourth session) second inter-repetition rest intervals. During the rests, the load was held in a full extension position by the subjects. After each set, the subjects had a passive recovery. All testing sessions (1-4) were separated by a minimum of 72 hours' recovery.

Statistical analysis

A repeated measure one-way ANOVA was used to compare repetitions per set to exhaustion with three inter-repetition rests. Multiple comparisons with a confidence interval adjustment by the LSD (Least Significant Difference) method were used as post hoc when significant main effects were determined. Significance was set at p<0.05 for all analyses. All statistical analyses were performed with SPSS version 17.0 (SPSS Inc., Chicago, IL).

RESULTS

The average repetition to exhaustion for each set under three IRRs is presented in Table 1. The number of BP and LP repetitions to exhaustion were significantly different in most exercise sets with different IRR periods (see Figures 1 and 2). A significant main effect was found for set 1 ($F_{2,57}$ = 7.403, p<0.05), set 2 ($F_{2,57}$ = 4.484, p<0.05 , set 3 ($F_{2,57}$ = 5.594, p<0.05) and set 4 ($F_{2,57}$ = 3.375, p<0.05) of BP. A significant main effect was also found for set 1 ($F_{2,57}$ = 4.928, p<0.05), set 2 ($F_{2,57}$ = 6.583, p<0.05) and set 3 ($F_{2,57}$ = 3.348, p<0.05) of LP. A four-second IRR demonstrated significant decreases in SR across each set when compared to the other IRR protocols (p<0.05).

Table 1. Repetitions in four consecutive sets (Mean ± SD)

Exercise	IRR (Second)	Set 1 Mean ± SD	Set 2 Mean ± SD	Set 3 Mean ± SD	Set 4 Mean ± SD
	0	12.25 ± 1.77	9.70 ± 2.17	8.35 ± 2.36	6.80 ± 2.30
BP	2	10.95 ± 1.05	8.20 ± 1.32	6.60 ± 1.27	5.40 ± 1.46
	4	10.55 ± 1.46	8.30 ± 1.33	7.00 ± 1.33	5.85 ± 1.26
	0	12.80 ± 1.29	10.80 ± 1.47	8.85 ± 1.69	7.05 ± 1.53
LP	2	11.75 ± 0.78	9.40 ± 0.99	7.70 ± 1.08	6.25 ± 1.25
	4	11.95 ± 1.09	9.65 ± 1.38	7.90 ± 1.65	6.35 ± 1.69

Legend: BP: bench press, LP: leg press, IRR: inter-repetition rest

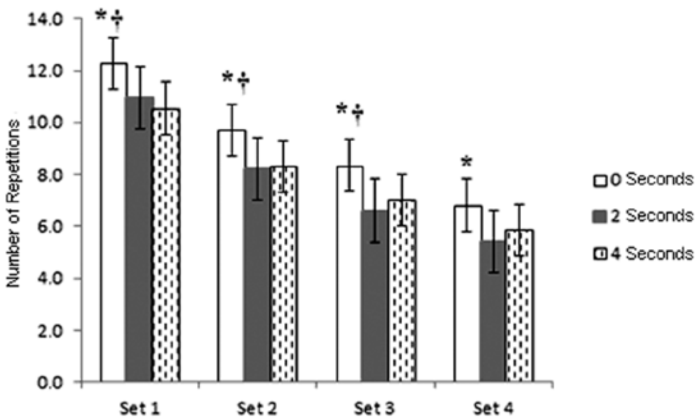

Figure 1. Repetitions related to performance patterns: BP means repetition
*A significant difference in 0 vs. 2 second IRR ($p < 0.05$). †A significant difference in 0 vs. 4 second IRR ($p < 0.05$).

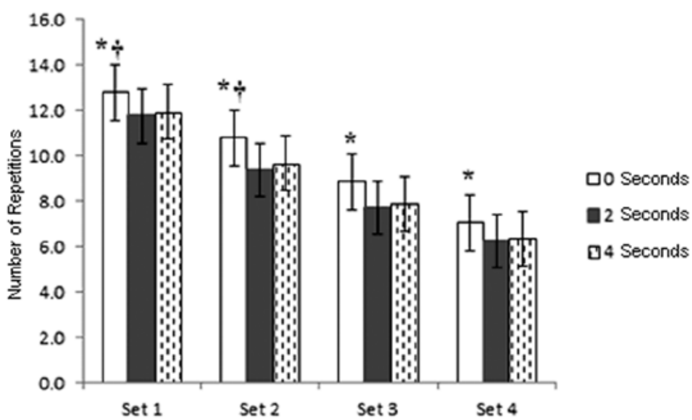

Figure 2. Repetitions related to performance patterns: LP means repetition
*A significant difference in 0 vs. 2 second IRR ($p < 0.05$).† A significant difference in 0 vs. 4 second IRR ($p < 0.05$).

DISCUSSION

The purpose of this study was to investigate the effect of different inter-repetition rest intervals on the sustainability of bench and leg press repetitions. To achieve this goal, we compared the repetitions during bench and leg presses that incorporated 0, 2 and 4 second inter-repetition rest periods. The primary finding in this investigation is the number of BP and LP repetitions to exhaustion in sets 1 and 2 with zero seconds of IRR was significantly higher than 2 and 4 second IRR, and there was no significant difference between 2 and 4 second IRR intervals in sets 1 and 2.

There were also no significant differences between the number of repetitions with 2 or 4 second IRR in sets 3 and 4. Yet the number of BP and LP repetitions with zero seconds of IRR was significantly different than two-second IRR in sets 3 and 4. This relationship in set 3 of BP was significant compared to a four-second IRR. The other finding of the present study was that there was no significant relationship between the total repetition of 2 and 4 second IRR (Figures 1 and 2). As the subjects completed subsequent sets in each protocol, the sustainability of the bench and leg press repetitions decreased significantly with an associated increase in IRR (Figures 1 and 2). The number of BP and LP repetitions to exhaustion from set one to set four was significantly higher in zero-second IRR periods than 2 and 4 second IRR periods.

Rest interval length is a highly important component of a resistance training protocol and a change in this component specifies the degree of specific intended physiological adaptations such as increased muscular strength and hypertrophy *and this factor can lead to longer volumes of work* (Rahimi, Boroujerdi, Ghaeeni, & Noori**,** 2007**).** When multiple sets of an exercise are performed to muscular failure, the inter-set rest interval has a significant impact on the number of repetitions completed and a higher volume (resistance × sets × repetitions) provides a greater stimulus for strength gains (Willardson, 2008).

The rest interval between sets is an important variable that affects both acute responses and chronic adaptations to resistance exercise programmes. In addition, if 2 to 3 sets of an exercise are performed, then at least 2 minutes of rest are needed to maintain repetition (Salles et al., 2009). The sequence of performing a series of exercises is therefore related to the inter-set rest intervals. Several studies have shown a significant reduction in the number of completed repetitions for some exercises that are performed later rather than earlier in an exercise session (Carpinelli, 2010). Mirzaei and co-workers (2008) compared the sustainability of bench press repetitions with different rest intervals. During each session out of seven testing sessions, four consecutive bench press sets were performed at 60% or 90% of 1RM and with a 90, 150 or 240 second rest intervals between the sets. The results showed that for each load a significant reduction in repetition occurred between the first and fourth sets and the 240 second rest between sets resulted in a greater sustainable total of repetitions vs. 90 or 150 seconds of rest between sets. A limitation of these studies (Mirzaei, Arazi, & Saberi, 2008) was the evaluation of single exercises and different rests. Therefore, for athletes involved in resistance training programmes to improve their maximum strength it must be considered that the rest interval length between sets is a critical component of resistance training programmes and this factor can lead to greater volumes of work.

The accumulation of lactic acid has been shown to lower intracellular PH through the dissociation of hydrogen ions (H^+), which results in muscle fatigue (Westerblad, Allen, & Lännergren, 2002). When the rate of H^+ production exceeds the rate of the capacity to buffer or remove protons from skeletal muscle, there is not enough time to buffer or remove H^+ muscle fatigue (Rahimi, 2005). The ATP that is supplied from non-mitochondrial sources and is finally used to fuel muscle contraction increases proton release, and causes the acidosis of intense exercise. Lactate production increases in these cellular conditions to prevent pyruvate accumulation and supply the NAD^+ needed for phase two of glycolysis (Robergs, Ghiasvand, & Parker, 2004). Therefore, the perception of increasing effort during resistance training may be associated with an increased reliance on anaerobic glycolysis and the inability to buffer hydrogen ions rather than immediate energetic pathways such as the ATP-PC system. Earlier research indicated a strong relationship between decreases in force production and associated decreases in phosphocreatine (PCr) during high-intensity exercise in skeletal muscle (Bogdanis Nevill, Boobis, Lakomy, & Nevill, 1995; Bogdanis, Nevill, Boobis, & Lakomy, 1996; Miller et al., 1987) and therefore PCr depletion may act to decrease SR. It can be hypothesised in the current examination that the decreases in SR were caused by drops in PCr levels in muscles. However, since PCr was not measured in this study we cannot conclude this definitively. This represents a limitation of this examination. In the current study, the zero-second IRR has more effect on delayed fatigue which allowed the subjects to complete a greater repetition of training vs. the 2 and 4 second IRR periods. Post hoc analyses indicated that the 2 and 4 second IRR periods decreased the sustainability of repetition. This may be explained by IRR allowing partial recovery from exercise and perhaps due to H^+ production exceeding the rate of the capacity to buffer or remove and deficiency in the intercellular buffering system. However, the times of all sets with 2 and 4 second IRR intervals were longer vs. the zero-second IRR and caused an increase in the accumulation of lactic acid. Because the volume was not laid down completely after every single repetition, the involved muscles were unable to fully rest for 2 or 4 seconds in the third and fourth sessions, respectively. This may be explained by IRR allowing partial recovery from exercise, thereby decreasing the SR. This is similar to the findings of Kraemer and co-workers (1987). In summary, this study examined the association between IRR, fatigue and SR during resistance exercise. To date, no study has examined the relationship between IRR and SR during such exercise. Accordingly, this was the one of the first studies to examine the effect of IRR on SR during a BP and LP exercise protocol (75% of 1RM). Future studies should examine strength gains resulting from long-term training with longer IRR intervals and different ISR periods for the same or distinct muscle groups. The results of the current study may hold particular relevance for programmes designed to boost the sustainability of repetitions per set.

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