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Section III – Sports Training

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Does Tempo of Resistance Exercise Impact Training Volume?

by
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Volume and intensity of exercise are the basic components of training loads, having a direct impact on adaptive patterns. Exercise volume during resistance training has been conventionally evaluated as a total number of repetitions performed in each set, regardless of the time and speed of performing individual exercises. The aim of this study was to evaluate the effect of varied tempos i.e. regular (REG) 2/0/2/0, medium (MED) 5/0/3/0 and slow (SLO) 6/0/4/0 during resistance exercise on training volume, based on the total number of performed repetitions (REP_{sum1-5}) and time under tension (TUT_{sum1-5}). Significant differences in TUT (s) were found in particular sets for each tempo of 2/0/2/0, 5/0/3/0 and 6/0/4/0 ($p < 0.001$). The ANOVA also revealed substantial differences in the REP for individual sets ($p < 0.001$). Post-hoc analyses showed that TUT for each set and total TUT_{sum1-5} were significantly higher in the 5/0/3/0 and 6/0/4/0 tempos compared to 2/0/2/0 ($p < 0.001$). REP was significantly higher for the 2/0/2/0 tempo compared to 5/0/3/0 and 6/0/4/0 tempo in each set. Total REP_{sum1-5}, TUT_{sum1-5} between 5/0/3/0 and 6/0/4/0 tempos were not significantly different. The main finding of this study is that the movement tempo in strength training impacts training volume, both in terms of repetitions and total time under tension.

Key words: *resistance training, tempo, volume, time under tension.*

Introduction

Development of muscle strength belongs to key components of conditioning in various sports. Scientific studies connected with strength training have mainly analysed such variables as exercise intensity, volume, number of sets, repetitions, duration of rest periods between sets and exercises (Bird et al., 2005; Golas et al., 2017; Kraemer et al., 2002). The effect of these variables on the process of muscle adaptation has been extensively explored and discussed. However, the results are not always unequivocal. Volume and intensity of exercise are the basic components of training loads, having a direct impact on adaptation patterns. Exercise volume during resistance training has been conventionally evaluated as a total number of repetitions performed in each set, regardless of the time and speed of individual exercises. However, one complete repetition may take from a few to more than ten seconds. Studies have found that the external load ranging from 30% 1RM to 95% 1RM results in similar hypertrophy (Burd et al., 2010; Fry, 2004; Mitchell et al., 2012; Wernbom et al., 2007). Therefore, examinations of other variables (such as movement speed) of resistance exercise is needed, because they can significantly influence training adaptations. Despite numerous scientific studies on resistance training, only few have analysed the effects of movement tempo (cadence) on adaptive processes in terms of strength, muscle power or muscle hypertrophy (Hatfield et al., 2006; Headley et al., 2011; Hunter et al., 2003;

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Keeler et al., 2001; Sakamoto and Sinclair, 2006; Westcott et al., 2001; Golas et al., 2016; Maszczyk et al., 2016; Wilk et al., 2018). The term tempo relates to the rate at which each repetition is performed. Changes in tempo, and consequently, the velocities in particular phases of the movement, can result from the effect of the external resistance, with the increase in the external load leading to the decline in maximal movement speed in the concentric phase (McArdle et al., 2015) or conscious control of individual movement cadences. Cadence is most often defined by means of several digits which correspond to particular movement phases. For example, 4/0/2/0 denotes a 4-second eccentric phase, no break in the transition phase, a 2-second concentric phase and no rest before the next repetition (King, 2002). Each of the forms of resistance training leads to hypertrophy or an increase in muscle strength (Schoenfeld et al., 2017), but training with controlled movement tempo can induce different post-exercise responses and long-term adaptations. A slower movement cadence has been often used to stimulate muscle hypertrophy (Gumucio et al., 2015), since faster uncontrolled speeds are typically employed to develop strength and muscle power (Bird et al., 2005). The number of repetitions performed at a specific tempo impacts total time under tension in a set (TUT_{set}). TUT provides accurate information about the duration of resistance effort for a set, and in the whole training session (TUT_{sum}). With a slow movement tempo, especially 5/0/5/0 or even extremely slow 10/0/10/10, performance of a lower number of repetitions in a set takes longer and has longer TUT than for a faster tempo with a higher number of repetitions. In this situation, determination of exercise volume using the number of performed repetitions is not very informative. Table 1 presents simulations of exercise volume in resistance training computed based on the number of performed repetitions and time under tension during a set (TUT_{set}), and the entire training session (TUT_{sum}). The simulation demonstrated that performing the highest number of repetitions with a tempo 2/0/2/0 does not mean the longest time under tension, both for a set and the entire training session. Therefore, the greatest number of repetitions does not translate into the longest time under tension.

Studies have found that the lower the movement speed, the more dynamic decline in maximal muscle force (Hutchins, 1993; Kraemer et al., 2002; Westcott et al., 2001). This was confirmed by Headley et al. (2011) who demonstrated that with a fast movement speed, athletes generated a higher level of maximal muscle force compared to the force recorded during slow tempo movements. Similar observations concern the number of repetitions. Sakamoto and Sinclair (2006) demonstrated that faster movement speeds helped perform more repetitions with a specific %RM load. Furthermore, the researchers found that in a group of people who performed exercises with much smaller volume (smaller volume resulted from a lower number of repetitions), but used a slower movement tempo, the post-exercise fatigue was higher, while a greater decline in muscle power was recorded compared to the group that used volitional speeds (Hatfield et al., 2006). Few previous studies have indicated that the protocols with various tempos (cadences) may lead to different post-exercise responses, both acute and chronic. Time under tension in a set (TUT_{set}) has an effect on the level of post-exercise metabolic and endocrine changes (Bird et al., 2005; Wilk et al., 2018). Extended time of constant muscle tension during a slow movement tempo has a beneficial effect on muscle hypertrophy (Bird et al., 2005; Keogh et al., 1999). There are also scientific reports which have shown that the independent change in cadences in particular phases of movement has an impact on post-exercise adaptations. Gumucio et al. (2015) demonstrated that slower cadence in the eccentric phase impacted muscle hypertrophy more than the extension of the concentric phase. More recent research has focused on extremely slow cadences and tempos (Hatfield et al., 2006; Westcott et al., 2001), whereas no studies have analysed more practicable and moderate tempos with variable cadences, both in the eccentric and concentric phases.

The aim of this study was to evaluate the effect of varied tempos i.e. regular (REG) 2/0/2/0, medium (MED) 5/0/3/0 and slow (SLO) 6/0/4/0 during resistance exercise on training volume based on the total number of performed repetitions (REP_{sum1-5}) and time under tension (TUT_{sum1-5}). We hypothesized that the change in movement tempo would have a significant effect on TUT and REP independently for individual sets, and on exercise volume (REP_{sum1-5}), as well as total time under tension (TUT_{sum1-5}) for the entire experimental training session.

Methods

Experimental Approach

All testing was performed in the Laboratory of Strength and Power at the Jerzy Kukuczka Academy of Physical Education in Katowice. The experiment was performed following a randomized crossover design, where each participant performed a familiarization session with a 1-RM test and three different testing protocols a week apart. During the experimental sessions, subjects performed five sets of the bench press exercise to failure using 70% 1RM and three different tempos: 2/0/2/0 regular tempo (REG), 5/0/3/0 medium tempo (MED) and 6/0/4/0 slow tempo (SLO). Subjects were required to refrain from resistance training 72 hours prior to each experimental session, were familiarized with the exercise protocol and were informed about the benefits and risks of the research before expressing their consent for participation in the study.

Participants

We examined 42 men (age: 20-37 years, body mass: 75.9 ± 7.7 kg, bench press 1RM: 112.4 ± 5.5 kg) with a minimum of one year of strength training experience (3.2 ± 0.87 years). Furthermore the participants were expected to be able to perform the bench press exercise with a load of at least 120% of their body mass. The participants were allowed to withdraw from the experiment at any moment and were free of injuries. The study protocol was approved by the Bioethics Committee for Scientific Research, at the Academy of Physical Education in Katowice, Poland, according to the ethical standards of the Declaration of Helsinki, 1983. Participants were instructed to maintain their normal dietary habits over the entire study period and did not use any dietary supplements or stimulants for the duration of the study.

Procedures

Familiarization session and one repetition maximum test

The participants arrived at the laboratory at the same time of day (in the morning between 09:00 and 11:00) and cycled on an ergometer for 5 minutes at an intensity that resulted in a heart rate of around 130 bpm, then performed a general upper body warm-up of 10 body weight pull-ups and 15 body weight push-ups. Next, the participants completed 15, 10, and 5 of the BP repetitions using 20 %, 40%, and 60% of their estimated 1RM using a 2/0/2/0 cadence. Hand placement on the barbell was individually selected, but the forefinger had to be inside of the 81-cm mark of a standard Olympic bar. The positioning of the hands was recorded to ensure consistent hand placement during all testing sessions. The participants then executed single repetitions using a volitional cadence with 5 min of rest between successful trials. The load for each subsequent attempt was increased by 2.5 kg, and the process was repeated until failure.

Experimental sessions

The participants arrived at the laboratory in the morning (09:00 to 11:00 am). After completing the same warm-up as in the familiarization session, they performed 5 sets of the BP with 70% 1RM using either a REG, MED or SLOW metronome guided cadence (Korg MA-30, Korg, Melville, New York, USA). Each set was performed to failure and with 3 min of rest between sets. The participants were verbally encouraged throughout all testing sessions. All repetitions were performed without bouncing the barbell off the chest, without intentionally pausing at the transition between the eccentric and concentric phases, and without raising the lower back off the bench.

Statistical analysis

All statistical analyses were performed using the STATISTICA software version 12 (StatSoft, Inc.) with $\alpha = .0.05$. The data were tested for normal distribution using the Shapiro-Wilk test. In order to verify whether significant differences occurred for the total of REP_{sum1-5} and TUT_{sum1-5}, analysis of variance (ANOVA) was performed between the tempos and between individual series of BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5} during the entire experimental protocol and post-hoc Tukey's tests were conducted. The F statistic and level of significance were evaluated. Homogeneity of variance was verified using the Levene's test at $p > 0.05$.

Results

All the data had normal distribution (W

ranged between 0.80 and 0.99). Significant differences in TUT (s) were found in particular sets (BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5}) for each tempo of 2/0/2/0, 5/0/3/0 and /6/0/4/0 ($p < 0.001$) (Table 2). The ANOVA also revealed substantial differences in the REP for individual sets BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5} ($p < 0.001$) (Table 5). Post-hoc analyses showed that TUT for each set BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5} and total TUT_{sum1-5} were significantly higher in the 5/0/3/0 and 6/0/4/0 tempos compared to 2/0/2/0, which means that 2/0/2/0 differed significantly between 5/0/3/0 and 6/0/4/0 ($p < 0.001$). Furthermore, the REP was significantly higher in the 2/0/2/0 tempo compared to 5/0/3/0 and 6/0/4/0 in each set (BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5}) and total REP_{sum1-5}. TUT and REP between 5/0/3/0 and 6/0/4/0 tempos were not significantly different. It was demonstrated that the participants performed more REP in particular sets (BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5}) at the 2/0/2/0 tempo (Figure 2), but TUT in all sets (BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5}) was highest when the 6/0/4/0 tempo was used (Figure 1). All values of TUT and REP for BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5} sets were summed and the differences in TUT_{sum1-5} and REP_{sum1-5} between 2/0/2/0 tempo, 5/0/3/0 and 6/0/4/0 were significant ($p < 0.001$) (Tables 2 and 4). TUT_{sum1-5} and REP_{sum1-5} between 5/0/3/0 and 6/0/4/0 were not significantly different.

Table 1

Simulations of exercise volume in resistance training

Number of repetitions	Tempo	Exercise volume for the set (n)	Time under tension for the set (s)	Number of sets	Exercise volume for the training session (n)	Time under tension for the training session (s)
8	2/0/2/0	**8**	32	5	**40**	160
4	5/0/5/0	4	40	5	20	200
3	10/0/10/0	3	**60**	5	15	**300**

n - computed from the total number of repetitions

Table 2

The level and differences in total TUT_{sum1-5} for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement.

Time under tension $_{sum1-5}$ (s)				
Tempo	*Mean (± SD)*		*F*	p
2/0/2/0	*124.65*	*33.66*		
5/0/3/0	*166.60*	*29.27*	24.18	0.0001
6/0/4/0	*178.89*	*33.69*		

Table 3

The level of differences in TUT for BP_{s1}-BP_{s5} sets for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement.

Set	Time under tension (s)			ANOVA	
	2/0/2/0	5/0/3/0	6/0/4/0	F	*p*
BP_{s1}	32.52 ± 8.10	45.95 ± 15.62	49.53 ± 17.02	8.89	0.0004
BP_{s2}	28.52 ± 8.50	39.80 ± 16.21	42.41 ± 17.19	5.72	0.005
BP_{s3}	24.43 ± 7.02	34.90 ± 17.00	39.41 ± 17.77	5.92	0.005
BP_{s4}	21.61 ± 7.48	32.15 ± 17.61	35.29 ± 18.54	4.80	0.01
BP_{s5}	20.41 ± 6.22	31.80 ± 17.75	32.76 ± 19.17	4.29	0.02

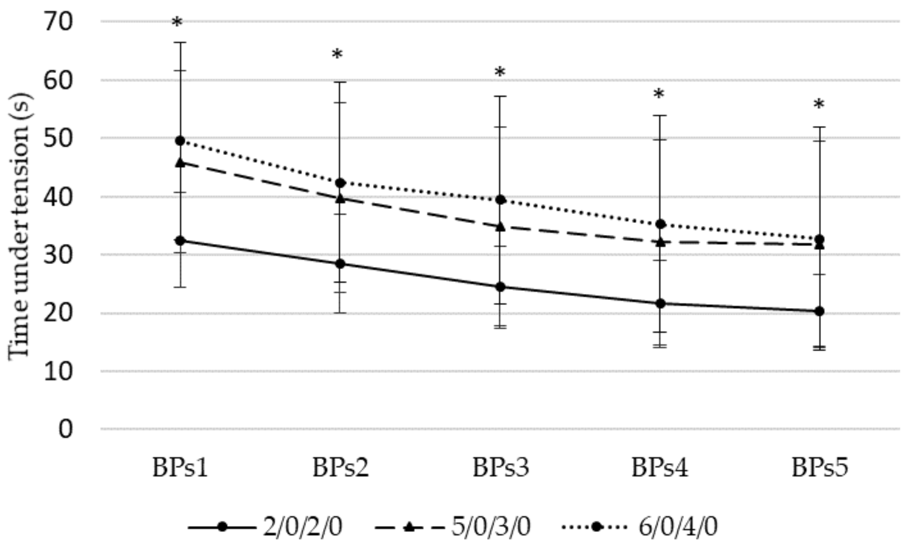

Figure 1

TUT(s) for BP_{s1}-BP_{s5} for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement.

Table 4

The level and differences in total REP_{sum1-5} for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement.

Number of repetitions $_{sum1-5}$ (n)			
Tempo	Mean (± SD)	F	*p*
2/0/2/0	28.32 ± 6.86		
5/0/3/0	18.75 ± 4.14	25.76	0.0001
6/0/4/0	15.71 ± 4.03		

Table 5

The level of differences in REP for BP_{s1} -BP_{s5} sets for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement.

Set	Number of repetitions (n)			ANOVA	
	2/0/2/0	5/0/3/0	6/0/4/0	F	*p*
BP_{s1}	7 ± 1	4 ± 1	4 ± 1	24.18	0.00001
BP_{s2}	6 ± 1	4 ± 1	3 ± 1	20.86	0.0001
BP_{s3}	5 ± 1	3 ± 1	3 ± 1	19.98	0.0001
BP_{s4}	4 ± 1	3 ± 1	2 ± 1	14.78	0.0001
BP_{s5}	4 ± 1	3 ± 1	2 ± 1	16.81	0.0001

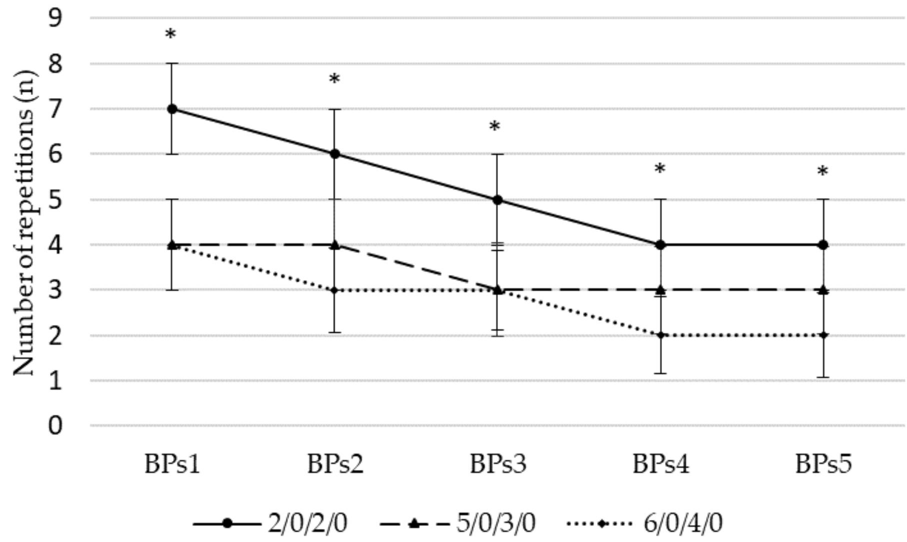

Figure 2

REP for the REG 2/0/2/0, MED 5/0/3/0 and SLOW 6/0/4/0 tempos of movement for BP_{s1}-BP_{s5} sets.

Discussion

The main finding of this study is that the movement tempo in resistance exercise impacts training volume, both in terms of repetitions and total time under tension. The study demonstrated significant differences in TUT_{sum1-5} and REP_{sum1-5} between REG 2/0/2/0 and MED 5/0/3/0, SLOW 6/0/4/0 tempos, despite using the same %RM and exercise to volitional muscular failure. The highest volumes in the experiment, based on the total number of repetitions REP_{sum1-5} was observed for REG (28.32 ± 6.86 REP), whereas the lowest, for the SLOW (15.71 ± 4.03 REP) tempo. Furthermore, the highest TUT_{sum1-5} was registered for SLOW (178.8 ± 33.69 REP) i.e. tempo for which the smallest training volume computed from the number of repetitions was obtained. The reverse pattern was observed for the REG tempo, with the highest training volume (based on REP_{sum1-5}) related to the shortest duration of the exercise. This leads to the conclusion that the longest duration of exercise does not necessarily mean the highest training volume, which is contradictory to the standpoint of the training load analysis. The results of the study indicated that even a small ((few seconds) modification in terms of tempo or cadence of particular movement phases can impact maximal REP, time under tension and, importantly, exercise volume in a set and in the whole training session. Movement tempo impacts training volume and, consequently, the level of post-exercise fatigue and adaptation patterns. The effect of a stronger training stimulus in case of the slow movement tempo can be observed even if the slower tempo leads to a decline in resistance training volume computed based on the number of repetitions as it was the case in our study. This is consistent with a study by Wilk et al. (2018), who documented higher post-exercise changes in testosterone, cortisol, CK and LA levels using the 6/0/2/0 tempo compared to the 2/0/2/0. Similarly, Antonutto and Prampero (1995) found significantly higher post-exercise blood lactate (BL) levels using a slow movement tempo. Hatfield et al. (2006) demonstrated that athletes who used slow movement tempos had, despite performing a smaller number of repetitions (and consequently lower exercise volume), greater post-exercise declines in generated muscle power compared to subjects who used a faster tempo. All these research reports demonstrated that movement tempo impacts not only exercise volume and post-exercise fatigue. Significant changes in TUT and REP in our study concern not only the entire experimental unit, but also individual values for each set (BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5}). The study demonstrated a significantly higher REP in case of the REG tempo for BP_{s1}, BP_{s2}, BP_{s3}, BP_{s4}, BP_{s5} and the opposite significantly higher TUT for individual sets in case of the MED and SLOW tempos. A higher number of repetitions (REP) in particular sets at REG tempo can be attributable to the use of elastic energy during the eccentric phase of contraction and its recovery during the concentric phase (Lindstedt et al., 2002). The results confirm previous findings published by Sakamoto and Sinclair (2006), who demonstrated that faster movement tempos helped perform more repetitions with a specific %RM (Table 4). Kraemer et al. (2002) and Westcott et al. (2001) demonstrated that slower movement tempo led to a decline in maximal muscle strength and, consequently, a decline in the number of repetitions, which is consistent with our results. Changes in TUT_{set1-5} between SLOW, MED and REG tempos (Table 2) are observed in movement speed during both, the concentric and eccentric phases, but it seems that a particular slowdown of the movement in the eccentric phase can significantly impact total TUT (Wilk et al., 2018). The eccentric phase of the movement requires even 6 to 7 times lower oxygen demand compared to the concentric phase (Lastayo et al., 1999), which can have a direct impact on the results and significantly higher value of both TUT_{set1-5} and TUT_{sum1-5} at SLOW and MED tempos compared to REG tempo of movement (Table 2). Extending the duration of the eccentric phase of the movement is likely to be beneficial to skeletal muscle hypertrophy (Bird et al., 2005; Gumucio et al., 2015; Roig et al., 2009; Schoenfeld et al., 2017). Some authors provided evidence that lower speed during the eccentric phase led to increased muscle tension (Golas et al., 2018), and had a beneficial effect on muscle hypertrophy (Bird et al., 2005; Burd et al., 2011; Gehlert et al., 2015), whereas extended duration of muscle tension stimulated protein synthesis (Burd et al., 2010). The final value of TUT has a significant effect on the degree of mechanical and physiological post-exercise responses that have an impact on muscle adaptation. If time under tension increases, the volume of the work also increases, regardless of the number of performed repetitions.

The results of our study and previous scientific reports about the impact of movement tempo in resistance training indicate that TUT for a set and the entire training session can have a significant effect on the pattern and efficiency of adaptive processes. Tempo represents a component of resistance training, which should be controlled and taken into consideration during planning and following the resistance training programs. Slower movement speeds allow for extension of exercise duration, while reducing the number of repetitions. This observation undermines the legitimacy of the previously used method to determine resistance training volume based only on the number of performed repetitions. This allows to conclude that movement tempo and time under tension, rather than the number of repetitions are fundamental variables in evaluation of training volume and optimization of adaptive changes in the neuro-muscular system. However, there is a need for the analysis of movement speed as another strength training variable. We suggest to evaluate the influence of this variable at various exercise intensities, using identical resistance training protocols.

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