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ORIGINAL ARTICLE

The slow exercise tempo during conventional squat elicits higher glycolytic and muscle damage but not the endocrine response

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Abstract

OBJECTIVE: The squat exercise is one of the most exhaustive ones in which different resistance training methods can elicit various changes in the concentration of many metabolites circulating in the blood. Therefore, this study aims to assess the differences between slow (5/0/3/0) and conventional (2/0/2/0) barbell squat movement tempo to concentric failure on acute metabolites and hormonal responses.

MATERIALS AND METHODS: Ten experienced powerlifters (24.3 ± 3.2 y; 77.9 ± 7.2 kg; 141 ± 17.5 kg Squat 1RM) who compete at the national and international level performed five sets of the barbell squat exercise (SQ) to failure at load 80% 1RM with two different tempos of movement: a 2/0/2/0 medium tempo (MED) and a 5/0/3/0 slow tempo (SLO) randomly one week apart. Venous blood samples (10ml) were collected from the antecubital vein, to determine acute pre and post-exercise values of testosterone (T), growth hormone (GH), insulin-like growth factor I (IGF-1), cortisol (C), creatine kinase (CK), and lactate acid (LA).

RESULTS: The SLO protocol resulted in higher time under tension ($p<0.01$) and a lower number of performed repetitions ($p<0.01$) than the MED protocol. Both exercise protocols test showed a high increase of T, C, GH, IGF-1, CK, and LA between pre and post-exercise ($p<0.01$). Performing 5 sets of SLO squats resulted in a higher post-exercise increase of LA ($p < 0.03$) and CK ($p < 0.02$) than MED protocol. There were no other significant differences in analyzed endocrine variables. Therefore, the SLO exercise tempo elicits higher lactate and muscle damage, but not the acute hormonal response.

CONCLUSION: This study demonstrated that in terms of endocrine response, the optimal moderate exercise tempo results in a high endocrine response, which is not dramatically increased by a longer time under tension resulting from slow exercise execution. On the other hand, slow speed resulted in a prolonged time under tension, more muscle damage, and lactate production; which may play a large role in stimulating muscle growth and tissue regeneration.

INTRODUCTION

The squat exercise (SQ) physically exhaustive and allow to lift of high external load causing tremendous physiological responses (Blazek *et al.* 2019, Reader *et al.* 2016, Schoenfeld *et al.* 2019). Since the SQ is used in many different resistance training methods its variable use can elicit various changes in the concentration of many metabolites circulating in the blood. Those metabolites and hormonal accumulation during and after resistance training are the primary stimuli for gains in strength and muscle hypertrophy (Shoenfeld 2010), where the key hormones in training adaptations are testosterone (T), growth hormone (GH), and cortisol (C). Another important indicator of physiological responses to stress induced by resistance training is blood lactate (BL) and creatine kinase (CK), where those hormones and metabolites affect the hypertrophy changes occurring after a resistance training program due to interaction with specific androgen receptors (Kvorning *et al.* 2006; Shoenfeld 2012).

There is a consensus that the endocrine responses to resistance exercise depend on training characteristics such as the amount of muscle mass activated, the exercise order, the load used, the number of repetitions (REP) performed per set, the number of sets per exercise, and the length of rest interval between sets. Resistance exercise protocols of high volume (3–6 sets; 8–12 REP), moderate load (60–85%1RM), and short rest intervals (30–90 s), which activate large muscle groups, elicit the greatest acute elevations in GH, T, and C (Crewther *et al.* 2008; McCaulley *et al.* 2009; Ahtiainen *et al.* 2005; Boroujerdi and Rahimi 2008; Beaven *et al.* 2008;). However, there are no guidelines regarding the tempo of movement in these recommendations.

Movement tempo also affects the level of biological stress during and after resistance training and thus, the post-exercise endocrine response (Headley *et al.* 2011, Wilk *et al.* 2018b). However, the results of the research on metabolic and endocrine responses after training with different movement tempo are not conclusive. A study by Hunter *et al.* (2003) compared the post-exercise changes in concentration of BL between 5/0/10/0 and 1/0/1/0 movement tempo. Although the time duration of training sessions in both tempos was equal (29 min), BL was significantly greater after training with faster compared to a slower tempo. In contrast, Mazzetti *et al.* (2007), Wilk *et al.* (2018b), and Martins-Costa *et al.* (2016) showed that the training with slower movement tempo resulted in greater post-exercise increases in BL compared to training with a faster tempo. Headley *et al.* (2011) did not show differences in the post-exercise level of BL as well T, GH, C after training with the tempo 2/0/2/0 compared to tempo 4/0/2/0. In contrast, the study of Headley *et al.* (2011) and Goto *et al.* (2008) found greater T, GH, and C responses after training with the slower movement tempo (3/0/3/0) compared to faster (1/0/1/0). The results of these studies indicate that the movement tempo is a parameter of resistance training that has a significant impact on metabolic and hormonal post-exercise changes, however, it still has not been shown which tempo of movement (slow or fast) is more beneficial in post-exercise metabolic and endocrine changes.

The difference in metabolic and hormonal responses following resistance training with different movement tempo may be related to the mechanical characteristics of the protocols. A faster tempo of movement leads to an increase in the maximum number of repetitions in the sets compared to the slower tempo (Sakamoto and Sinclar 2006). However, a greater number of performed REP is not synonymous with longer TUT. During the slower movement tempo, there was observed a decrease in the maximal number of REP, but at the same time, the total TUT increase compared to the faster tempo movement (Wilk *et al.* 2018b). A study by Goto *et al.* (2009) and Wilk et a., (2018b) suggested that extending of duration in particular REP and consequently extending TUT is an important factor stimulating acute metabolic and hormonal responses after resistance exercise, regardless of the number of performed REP.

Since there is no unambiguous indication of whether the changes in the tempo of movement affects the post-exercise metabolic and hormonal concentration, the main goal of this study was to assess the influences of slow (5/0/3/0) and conventional (2/0/2/0) barbell squat movement tempo to concentric failure on acute metabolites and hormonal responses. The secondary aim was to assess the volume of effort, the maximal number of REP, maximal time under tension (TUT), which were analyzed at the experiment.

MATERIALS & METHODS

Experimental Approach to the Problem

All testing was performed in the Strength and Power Laboratory at the Academy of Physical Education in Katowice. The experiment was performed in a randomized crossover design, where each participant performed a familiarization session with a 1-RM test and two different testing protocols a week apart. During the experimental sessions, subjects performed five sets of the barbell squat exercise (SQ) to failure at load 80% 1RM with two different tempos of movement: a 2/0/2/0 medium tempo (MED) and a 5/0/3/0 slow tempo (SLO). Subjects were required to refrain from resistance training 72 hours before each experimental session, were familiarized with the protocol and the benefits and risks of the examinations, and expressed their consent for participation in the study.

The following variables were analyzed independently for the MED and SLO movement tempo: TUT (Set 1-5) (s) - time under tension independently for each set (1 to 5), TTUT (s) – total time under tension for 5 sets, REP (Set 1-5) (n) – number of repetitions performed independently for each set (1 to 5), TREP (n) - total number of repetitions performed for 5 sets, Pre-Ex - pre-exercise blood samples, Post-Ex - post-exercise blood samples.

Subjects

The study examined 10 men (24.3 ± 3.2 y; 77.9 ± 7.2 kg; 141 ± 17.5 kg Squat 1RM) with at least three years of resistance training experience (4.7 ± 1.59 years). To be included in the study, subjects who participated must have been able to squat at least 150% of their body mass. The participants were allowed to withdraw from the experiment at any moment and were free of any pathologies or injuries. The study protocol was approved by the Bioethics Committee for Scientific Research, at the Academy of Physical Education in Katowice, Poland, and performed according to the ethical standards of the Declaration of Helsinki, 1983. Subjects were instructed to maintain their normal dietary habits for the duration of the study period and did not use any dietary supplements or stimulants for the duration of the study.

Procedures

1RM Strength Testing

All testing was performed in the Strength and Power Laboratory at the Academy of Physical Education in Katowice. Participants arrived at the laboratory between 9:00 and 11:00 a.m. and cycled on an ergometer for 5 minutes, which was followed by a general upper body warm-up of 10 pull-ups and 15 push-ups. Next, the participants completed 15, 10, 5, and 3 barbell squat repetitions using 20%, 40%, 60%, 80% of their estimated 1RM using the voluntary tempo of movement. The participants then executed single repetitions with 5 min of rest between successful trials. The load for each subsequent attempt was increased by 5 and 2.5 kg, and the process was repeated until failure. For the SQ, absolute strength was taken as the maximum load lifted. An IPF Eleiko bar and weight plates (Eleiko, Sport AB Sweden) were used 1RM test.

Experimental sessions

The participants arrived at the laboratory in the morning (09:00 to 10:00 am) and were seated for 15 min before pre-exercise blood samples were taken. After completing the same warm-up as in the familiarization session, they performed 5 sets of SQ at 80% 1RM using tempo MED (2/0/2/0) or SLO (5/0/3/0) metronome guided tempo (Korg MA-30, Korg, Melville, New York, USA). Each experimental set was performed to concentric failure. The break between the series was 3 min. The time between experimental sessions of training was one week. The participants were verbally encouraged throughout all testing sessions. After the final set, blood samples were then collected 1 min (Post) after exercise.

All familiarization and experimental sessions were recorded using a Sony camera (FDR191 AX53). Time under tension and the number of performed repetitions were obtained manually from the recorded data using slow-speed playback (1/5 speed). To ensure the reliability of manual data collection, four independent researchers analyzed the data from the Sony camera (Wilk *et al.* 2019b). There were no significant differences in the TUT (s), TTUT (s), and REP (n), and TREP (n) between the data collected by 4 evaluators. All participants completed the described testing protocol.

Tab. 1. The testing protocols were applied during the experiment.

	Units	Analyses method
Growth hormone	ng/ml	DSL-1900 radioimmunoassay test of serum
IGF-1	ng/ml	DSL-2800 test of serum
Cortisol	ug/dl	DSL-2100 radioimmunoassay test of serum
Testosterone	ηg/dl	DSL-4000 radioimmunoassay test of serum
Blood Lactate	ng/dL	UV-1201 Shimadzu spectrophotometer test of serum
Creatine kinase	mg/dl	UV-1201 Shimadzu spectrophotometer test of serum

Biochemical analyses

Venous blood samples were obtained from the cubital vein (10ml), maintained at ambient temperature for

Tab. 1. Time under tension at different barbell squat tempo of an exercise

Sets	Time Under Tension (s)		Repetitions (n)	
	2/0/2/0	5/0/3/0	2/0/2/0	5/0/3/0
SQ_{Set1}	70 ± 9.7*	87.5 ± 18.0	17.6 ± 2.4*	10.8 ± 2.3
SQ_{Set2}	49.2 ± 6.5*	70.9 ± 11.9	12.4 ± 1.6*	9 ± 1.5
SQ_{Set3}	41 ± 6.8*	62.7 ± 10.0	10.4 ± 1.7*	8 ± 1.3
SQ_{Set4}	38.1 ± 8.5*	59.5 ± 6.9	9.7 ± 2.1*	7.4 ± 0.9
SQ_{Set5}	38.5 ± 4.8*	57.6 ± 9.7	9.6 ± 1.2*	7.2 ± 1.2
$Total_{Set1-5}$	236.8 ± 22.0*	338.2 ± 43.1	59.4 ± 5.5*	42.4 ± 5.4

*Statistically different between medium and slow tempo protocol at $p < 0.001$.

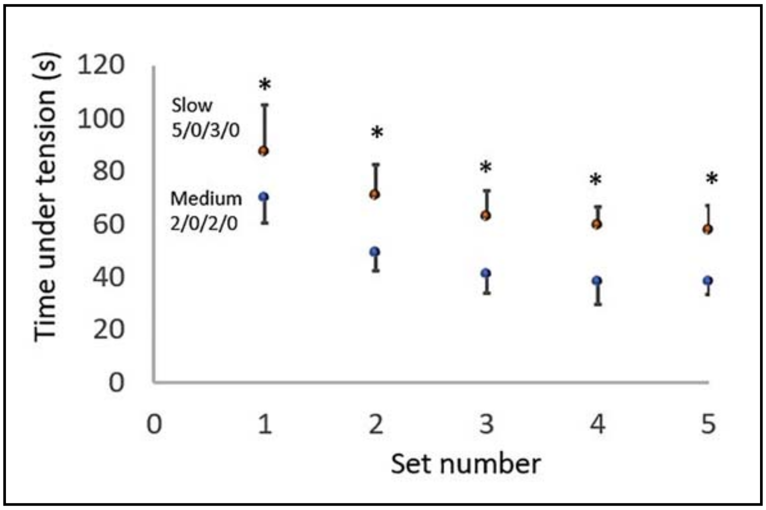

Fig. 1. Time under tension at different barbell squat tempo of an exercise

45 minutes, and then centrifuged for 10 minutes at 2,000 rpm. The serum was then removed and frozen at –70° C for later analysis. In each case 10 ml of venous blood to determine pre-and post-exercise biochemical values of the analyzed variables at rest, 1 minute after the cessation of the last set of squats. Samples were analyzed in duplicate in the same assay run to avoid intraassay variance (Table 1). The intra-assay variance was less than 5% for all assays.

Statistical Analyses

All statistical analyses were performed with STATISTICA version 12 (StatSoft, Inc., Tulsa, OK, USA) with $\alpha = 0.05$. Data normality was tested using the Shapiro Wilk test. To determine whether differences were present for the number of REP performed and TUT, 2 x 5 (protocol x set) repeated measures analyses of variance (ANOVA) were performed and followed up with Tukey´s post-hoc tests. For blood markers, 2 x 2 (protocol x time) repeated measures ANOVA were performed and followed up with Tukey´s post-hoc tests. The increases in exercise-induced hormone concentration (Δ value) were determined as absolute differences between the pre-exercise value and the peak value of post-exercise.

RESULTS

All variables were normally distributed according to the Shapiro Wilk test, and data were expressed as mean and standard deviation (Table 1, Figures 1 and 2). The repeated measure ANOVA analyses showed differences between MED and SLO protocol ($p < 0.001$), where post hoc test showed that each performed set resulted in bigger TUT in SLO protocol than MED protocol, and each MED protocol resulted in a higher repetition number than SLO protocol (Table 1, Figure 1 and 2).

The protocol x time ANOVA for repeated measurements showed differences between pre and post-exercise levels of cortisol, testosterone, GH, and IGF-1, where each marker was increased after each exercise protocol (Table 2). The differences between post-exercise protocols were found for lactate and CK, where SLO protocol showed higher values than MED protocol. No other significant differences were found by the ANOVA test.

DISCUSSION

The main finding of this study is that the movement tempo did not cause significant differences in the level of the concentrations of the Post-Ex hormones after SQ

Tab. 2. Differences in blood markers between pre and post-exercise and between slow and medium tempo protocols.

	Tempo 2/0/2/0		Tempo 5/0/3/0	
	Pre	post	Pre	post
Cortisol	14.5 ± 5.0*	19.2 ± 4.5	12.8 ± 4.1*	16.82 ± 4.0
Growth hormone	0.15 ± 0.2*	13.7 ± 9.2	0,59 ± 1.5*	9,95 ± 7,3
IGF-1	211 ± 36*	258 ± 38	173 ± 28*	210 ± 35
Testosterone	539 ± 165,4*	778 ± 223	499 ± 140*	733 ± 168
Blood Lactate	229 ± 82	214 ± 42	242 ± 24	299 ± 20**
Creatine kinase	312 ± 93	384 ± 102	519 ± 255	636 ± 286**

*Differences between pre and post values in the same protocol, ** difference between tempo protocols in post-exercise measurement.

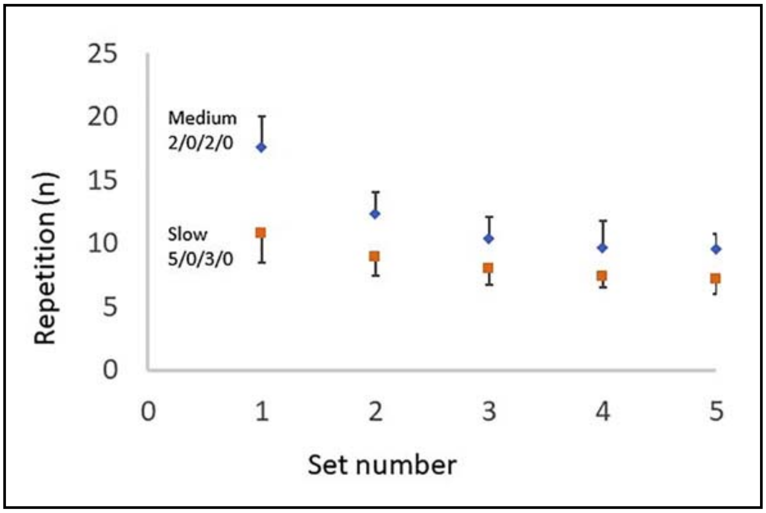

Fig. 2. Number of repetition at different barbell squat tempo of an exercise

to muscle failure. At the same time, the study showed significant differences in the level of the Post-EX concentrations CK and BL between SLO and MED tempos. Despite the exercise effort was to failure in every performed set, the result of the study showed differences in a maximal number of REPs per set 1-5, TUT set 1-5, and in every performed set in total values (TREP, TTUT).

Previous studies confirmed the acute hormone responses following different resistance training protocols. Resistance exercise protocols of high volume, moderate load, and short rest intervals, elicits the greatest acute hormonal and metabolic responses (McCaulley *et al.* 2009; Smilios et al 2003; Ahtiainen *et al.* 2005; Boroujerdi and Rahimi 2008; Beaven *et al.* 2008; Goto *et al.* 2003). These results are consistent with the results obtained in the presented study, where we demonstrated significant Post-Ex increase levels of C, GH, IGF-1, T, compared to Pre-Ex independently for MED and SLO movement tempo. However, it should be noted that there were no significant differences between Pre-Ex and Post-Ex levels of CK in training with MED and SLO movement tempo which is consistent with the results of Wilk *et al.* (2018c). Furthermore, the study did not show significant differences between Pre-Ex and Post-Ex levels of BL, but only in training with MED movement tempo.

Our study showed significant Post-Ex changes in metabolic and hormone concentrations compared to Pre-Ex, however, the main objective of the study was to assess the impact of movement tempo on the level of post-exercise metabolic and hormonal changes. The previous study indicates that among the many variables of strength exercise, training volume is the key factor stimulating the secretion of various hormones, both anabolic and catabolic (Wilk *et al.* 2018c). It should be noted that training with controlled movement tempo allows controlling REP, but also the TUT as an important variable in the evaluation of training volume (Wilk *et al.* 2018a, Burd *et al.* 2012, Headley *et al.* 2011). Important in the analysis of the obtained results is the fact that despite the implementation of a uniform effort for SQ with the MED and SLO movement tempos (5 sets; maximal number repetition to exhaustion; 80%1RM), the study showed significant differences in the TREP (42,4 ± 5.4 vs 59,4 ± 5.5 REP for MED and SLO) as well in TTUT (236,8 ± 22.0 vs 338,2 ± 43.1 s for MED and SLO). A significantly higher TREP was observed in training with MED, compared to the SLO tempo what is consistent with previous results (Sakamoto and Sinclar 2006, Hatfield *et al.* 2011). Contrary to TREP, the significantly higher TTUT was registered for SLO tempo compared to MED what is also consistent with previous studies (Wilk *et al.* 2018a, 2019c, Hatfield *et al.* 2011, Martins-Costa *et al.* 2016). However, the previous studies analyzing the influence of movement tempo on the number of TREP and value of TTUT was related to upper limb exercises. The results of the present study are the first to refer to the lower limbs exercise such as barbell squat. The result obtained in our research confirms that the change in movement tempo impacts the volume of effort (both REP and TUT) independently of the type of exercise used (upper or lower limbs).

The study by Goto *et al.* (2008, 2009) and Tanimoto *et al.* (2008) showed that tempo of movement impacts the level of absolute post-exercise hormonal changes after exercise performed to muscle failure. However, only one of the previous studies analyzed the absolute changes of post-exercise hormones after training at different movement tempos, taking into account the volume of effort is based on the number of performed REP and TUT. The study by Wilk *et al.* (2018b), as well as the results of the presented study, showed that slower movement tempo increases the TUT and decreases a maximal number of performed REP in every performed set, TREP, and TTUT. Despite the consistency of our result in TREP and TTUT with Wilk *et al.* (2018b) the metabolic and hormonal responses were different. Wilk *et al.* (2018b) showed significantly higher absolute differences of T after 5 sets of bench press with tempo 6/0/2/0 compared to tempo 2/0/2/0, and no differences BL and C level between used tempos. Contrary, the results of the present study did not show significant post-exercise differences between SLO and MED protocols in the levels of T and other measured hormones (GH, IGF-1, C) t. However, no available scientific data is analyzing GH and IGF-1 responses after SQ with different movement tempos which limits the possibility of comparing the obtained results.

The result of the presented study is contrary to the statement that a longer TUT during a preformed set significantly affects acute endocrine responses following resistance exercise (Wilk *et al.* 2018b). Although the presented study did not show significant absolute hormone differences between the SLO and MED movement tempo, significant differences in CK and BL levels were demonstrated. Higher absolute increases in CK and BL were observed after 5 sets of SQ with SLO compared to MED movement tempo. This is in agreement with results by Martins-Costa *et al.* (2016) who showed that longer TTUT significantly increases BL responses following resistance training. This result indicates that the slower movement tempo, with longer TTUT and lower number of TREP, increases post-exercise muscle damage (CK) glycolysis compared to faster movement tempo. The difference in metabolic responses following resistance exercise with different movement tempo may be related to the mechanical characteristics of the protocols. A faster tempo of movement leads to an increase in the maximum number of repetitions in the sets compared to the slower tempo (Sakamoto and Sinclar 2006), which might increase post-exercise blood lactate concentrations (Hatfield *et al.* 2006). However, a greater number of performed REP was not synonymous with longer TUT. TUT is considered important for inducing metabolic stress, although previous studies showed similar (Gentil *et al.* 2006) or smaller (Hunter *et al.* 2003) blood lactate responses in low load exercise with slow movement compared to the volitional tempo of movement what is constants with the presented result. It should be noted that differences in the size of the exercise muscles, the structure of the training programs, and the experimental approach used may explain the discrepancy of our results to other studies. Furthermore, the TTUT and the ratio of concentric to eccentric duration during each repetition may be an important factor influencing changes in endocrine responses.

The results of individual studies indicate that movement tempo is a valuable training variable and should be considered in the training process (Maszczyk *et al.* 2020). However, in the case of hormonal changes, the tempo of movement does not seem to be a basic factor conditioning post-exercise metabolic and hormonal changes in the blood. Other factors such as hormonal clearance rates, hormone degradation, receptor binding protein activation, and regulation should also be examined to gain more insight into the effects of movement velocity during resistance exercise on endocrine function, and consequently on tissue recovery and remodeling.

CONCLUSIONS

This study demonstrated that in terms of endocrine response, the optimal moderate exercise tempo results in a high endocrine response, which is not dramatically increased by a longer time under tension resulting from slow exercise execution. On the other hand, slow speed resulting in longer time under tension causes more muscle damage and lactate production, which may play a large role in stimulating muscle growth and tissue regeneration.

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