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O R I G I N A L A R T I C L E

Physiological responses to different neuromuscular movement task during eccentric bench press

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Abstract

OBJECTIVES: Increasing muscular hypertrophy is one of the main reasons for participating in a resistance training program, where different movement task such as eccentric cadences may serve as a potent hypertrophic stimulus and improve movement stability. Aim of this study was to investigate the physiological responses between slow 6/0/2/0 (SLOW) and moderate 2/0/2/0 (REG) eccentric cadences during five sets of bench press to failure using 70% 1 repetition maximum (1RM).

MATERIALS AND METHODS: Blood samples from sixteen men (21-29y, 85.9±7.7kg, 130±17.5kg bench press 1RM) with at least five years of resistance training experience were taken before, immediately after, 30 min after, and 60 min after both protocols in a randomized cross over study design.

RESULTS: ANOVA showed that more repetitions were performed during each set in REG and for the entire REG protocol ($p<0.001$), but total time under tension was greater during SLOW in each set and for the entire protocol ($p<0.001$). The post-exercise levels of lactate ($p=0.02$), creatine kinase ($p=0.04$), and testosterone ($p=0.01$) were greater after SLOW. Post-exercise cortisol levels decreased in both protocols ($p<0.001$), but these decreases were not significantly different between protocols.

CONCLUSIONS: Therefore, intentionally slow eccentric speeds and increased eccentric time under tension seem to be effective for increasing acute hormonal responses after exercise. As such, although a SLOW tempo may decrease the amount of total work (i.e. fewer repetitions with the same load), the increased time under tension seems to drive hormonal responses and neurological response, which may play a large role in stimulating muscle growth, coordination and movement stability.

INTRODUCTION

Increasing muscular hypertrophy is one of the most prominent reasons for participating in a resistance training program. To accomplish this and increase the physical preparation of different athletes for a variety of sports, resistance training variables can be adjusted to create a seemingly infinite number of different exercise intensity, set, repetition, and rest period combinations. Ultimately, these variables influence the total training volume and time the muscles spend under tension (TUT), two variables that have been positively associated with increasing muscular hypertrophy (Bird, Tarpenning, & Marino, 2005; Burd *et al.* 2010; Sienko *et al.* 2017). As training volume and TUT increase, metabolic and hormonal responses are subsequently affected, creating a mechanical and physiological milieu that encourages muscle growth (Bird *et al.* 2005; Lane *et al.* 2017).

Prescribing training volume is most often done by adjusting the external load and total number of repetitions, but TUT prescription typically receives less attention. There are two main methods of programming resistance training TUT: unrestricted, or explosive, movements in which TUT is not controlled; and "tempo" work during which a lifter performs the eccentric and concentric portions of a lift according to a predetermined cadence. Both methods have been shown to increase muscular hypertrophy (Schoenfeld, Grgic, Ogborn, & Krieger, 2017; Shiau & Te Hung Tsao, 2018), but tempo training may allow for more controlled and stabilized exercise programming. Most often, practitioners determine the cadence by using a series of numbers that correspond to certain phases of a lift. For example, a 4/0/2/0 cadence contains a 4-second eccentric phase, no pause during the transition phase, a 2-second concentric phase, and no rest before starting another repetition (King, 2002). The justification for controlling the eccentric contraction is also support by knowledge that controlled eccentric movement can increase the movement task stability (King, 2002).

Slower cadences have traditionally been used for stimulating skeletal muscle hypertrophy (Gumucio, Sugg, & Mendias, 2015), whereas faster, unrestricted speeds are typically used to develop speed and power attributes (Bird *et al.* 2005). Previous research has shown that on one end of the spectrum, a super slow cadence of 10/0/10/0 requires a relatively light load, which in turn negatively affects total training volume (Hatfield, Kraemer, Spiering, & Häkkinen, 2006). According to this logic, it is not surprising that others have shown that faster movement velocities result in greater hypertrophy compared to slower velocities (Farthing & Chilibeck, 2003; Shepstone *et al.* 2005), which can likely be credited to a greater amount of total work (Headley *et al.* 2011; Hunter, Seelhorst, & Snyder, 2003). Therefore, although increasing TUT has been associated with increased hypertrophy (Bird *et al.* 2005; Burd *et al.* 2010), it seems as though a super slow tempo results in a point of diminishing returns by way of a significantly decrease in training volume and total work.

In addition to increasing mechanical stress, increases in post-exercise levels of testosterone (T), lactate (LA), and creatine kinase (CK) levels have been associated with acute protein synthesis and chronic skeletal muscle growth (Crewther, Cronin, Keogh, & Cook, 2008; Hakkinen & Pakarinen, 1993; Kraemer *et al.* 1990; McCaulley *et al.* 2009; Smilios, Pilianidis, Karamouzis, & Tokmakidis, 2003; Uchida *et al.* 2009). Therefore, it may be advantageous to investigate how changes in resistance-training cadences affect these physiological responses.

To the best of the authors' knowledge, only one study has investigated the effects of different cadences (2/0/2/0 and 2/0/4/0) on metabolic and hormonal responses (Headley *et al.* 2011). Although this study indicated that the different tempos resulted in similar responses, only the concentric speed was altered, meaning that changes in eccentric speed remain uninvestigated. Since previous research indicates that increasing eccentric TUT seems to affect muscle growth to a greater extent than increasing concentric TUT (Gumucio *et al.* 2015), protocols with different eccentric tempos may result in different hypertrophic pre-cursor responses. The current body of literature focuses on polar ends of the tempo-spectrum (Hatfield *et al.* 2006; Westcott, Winett, Anderson, & Wojcik, 2001), and there is a lack of research investigating more practical, moderate tempos (Headley *et al.* 2011; Westcott *et al.* 2001). Therefore, the aim of this study was to investigate the physiological responses between slow 6/0/2/0 and moderate 2/0/2/0 eccentric cadences during the barbell bench press (BP). As a greater TUT with equal loads typically results in heightened physiological responses compared to less TUT (Bird *et al.* 2005; Burd *et al.* 2010), we hypothesized that the 6/0/2/0 cadence would induce greater total TUT and fatigue, resulting in fewer repetitions but greater increases in post-exercise lactate (LA), creatine kinase (CK), testosterone (T), and cortisol (C).

MATERIAL AND METHODS

Experimental Approach to the Problem

All testing was performed in the Laboratory of resistance training at the Jerzy Kukuczka Academy of Physical Education in Katowice, and 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 bench press exercise to failure using 70% 1RM and two different cadences: a 2/0/2/0 regular eccentric tempo (REG) and a 6/0/2/0 slow eccentric tempo (SLOW). Subjects were required to refrain from resistance training 72 hours prior to 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.

Subjects

The study examined 16 men (21-29 y, 85.9 ± 7.7 kg, 130 ± 17.5 kg bench press 1RM) with at least five years of resistance training experience (5.7 ± 1.29 years). To be included in the study, subjects must have been over 18 years old, participated in resistance training for at least 5 years, and must have been able to bench press 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 protocol of examinations and written consent of participants were approved by the Bioethics Committee in "xxx", 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 to use any dietary supplements or stimulants for the duration of the study.

Procedures

Familiarization session and one repetition maximum test

Subjects reported to the laboratory at the same time of day as the upcoming experimental sessions (in the morning between 07:00 and 11:00) and cycled on an ergometer for 5 minutes at an intensity that resulted in a heart rate around 130 bpm, followed by a general upper body warm-up of 10 body weight pull ups and 15 body weight push-ups. Next, subjects performed 15, 10, and 5 BP repetitions using 20kg, 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 91-cm mark on a standard Olympic bar. The positioning of the hands was recorded to ensure consistent hand placement during all testing sessions.

Subjects then executed single repetitions using a 1/0/X/0 cadence (where X is unrestricted) 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. After the 1RM was established, subjects rested for 3 minutes and then performed three sets of REG to failure and three sets of SLOW to failure with 70% 1RM and 3 min of rest between sets.

Experimental sessions

Subjects reported to the laboratory in the morning (8 - 9am) after a 10-h fast and were seated for 15 min before pre-exercise blood samples were taken (PRE). After completing the same warm-up as the previous session, subjects performed 5 sets of BP with 70% 1RM using either a REG 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 (Crewther *et al.* 2008; Kraemer *et al.* 1990; Smilios *et al.* 2003; Uchida *et al.* 2009). Subjects were verbally encouraged throughout all testing sessions (Brown & Weir, 2001). 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. After the final repetition was completed, blood samples were then collected 2 min (Post), 30 min (Post30), and 60 min (Post60) after exercise.

Blood sampling and analysis

Venous blood samples were obtained from the cubital vein (10ml), maintained in ambient temperature for 45 minutes, and then centrifuged for 10 minutes at 2,000 rpm. Serum was then removed and frozen at –70° C for later analysis. Serum C levels were determined using DSL-2100 radioimmunoassay, serum T levels were determined using DSL-4000 radioimmunoassay, LA was determined using a UV-1201 Shimadzu spectrophotometer, and CK was determined using an Analco GBG spectrophotometer. Samples were analyzed in duplicate in the same assay run to avoid inter-assay variance. The intra-assay variance was less than 5% for all assays.

Statistical analysis

All statistical analyses were performed with STATISTICA version 12 (StatSoft, Inc., Tulsa, OK, USA) with $\alpha = 0.05$. Data normality was tested using the Sharpio Wilk test. To determine whether differences were present for the number of repetitions 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 4 (protocol x time) repeated measures ANOVA were performed and followed up with Tukey´s post-hoc tests.

RESULTS

All data were normally distributed (W range between 0.89 to 0.98). The ANOVA tests revealed that differences were present between protocols for TUT ($p < 0.001$) and number of repetitions ($p < 0.001$). Post hoc tests revealed that subjects completed more repetitions in the REG protocol (*Figure 1*), but TUT was greater in the SLOW protocol (*Figure 2*). Both findings were observed during each set and when all 5 sets were summed together (*Figures 1 and 2*).

The ANOVA tests also showed significant effect for time for LA ($p = 0.02$) (*Figure 3B*), T ($p = 0.01$) (*Figure 3A*), C ($p < 0.01$) (*Figure 3C*), and CK ($p = 0.03$) (*Figure 3D*). Significant main effects for protocol were also observed for LA ($p = 0.02$), CK ($p = 0.04$), and T ($p = 0.01$). Post hoc analyses showed that post-exercise levels of LA, CK, and T were greater for the SLOW protocol compared to REG. Post-exercises C levels decreased in both protocols ($p < 0.001$), but these decreases were not significantly different between protocols. Follow-up tests revealed that C was significantly lower at Post30 and Post60 compared to PRE and Post.

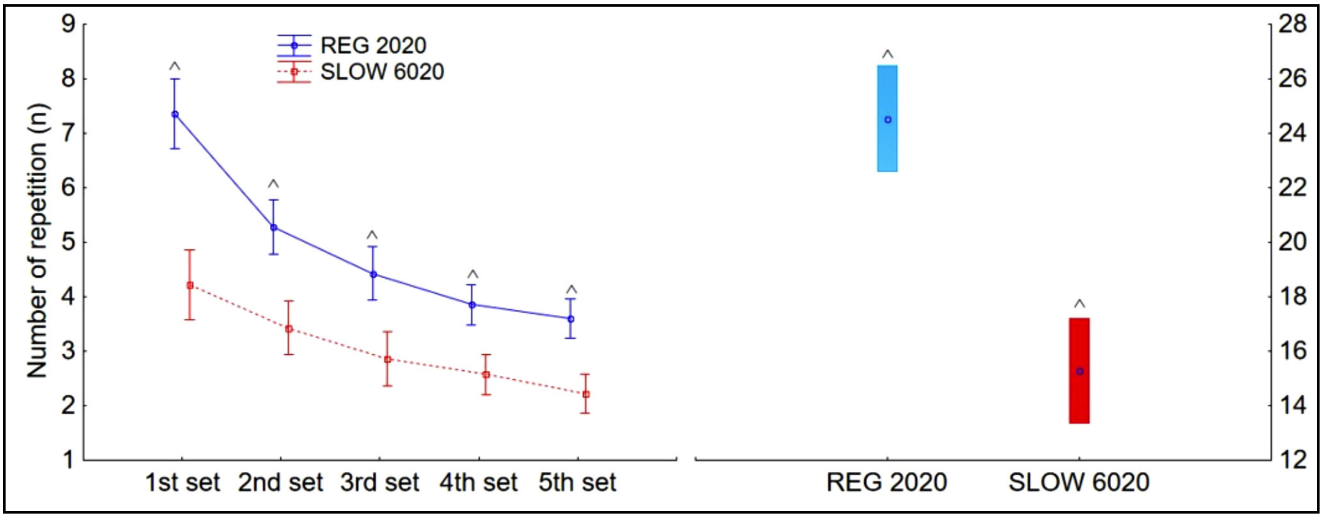

Fig. 1. Number of repetitions completed
Legend: REG = exercise protocol at regular tempo 2020, SLOW = exercise protocol with slow eccentric contraction 6020, ^ significantly different between REG and SLOW.

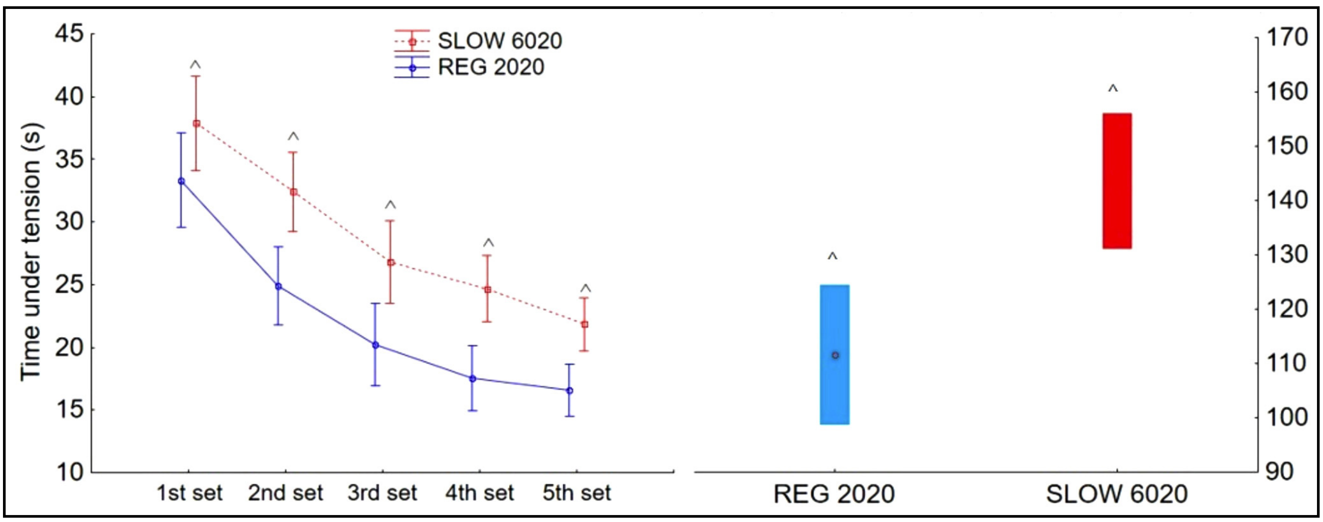

Fig. 2. Time under tension during exercise
Legend: REG = exercise protocol at regular tempo 2020, SLOW = exercise protocol with slow eccentric contraction 6020, ^ significantly different between REG and SLOW.

DISCUSSION

The main finding of this study is that although SLOW resulted in significantly fewer repetitions, the total TUT was greater than REG. Therefore, it seems as if LA, CK, and T concentrations are affected more by total TUT (when concentric TUT is similar and eccentric TUT is greater) than the number of repetitions completed when performing the BP with 70% 1RM. These data indicate that slower eccentric speeds may be more effective than faster eccentric speeds for stimulating muscle hypertrophy, even if purposefully increasing eccentric TUT results in fatigue and reduces resistance training volume.

Since external loads ranging from 30% 1RM to 95% 1RM ultimately result in similar hypertrophic outcomes (Burd *et al.* 2010; Fry, 2004; Mitchell *et al.* 2012; Wernbom, Augustsson, & Thomeé, 2007), it is necessary to investigate the effects of other resistance training variables, such as movement speed, to provide additional information for optimizing resistance training protocols. The present study indicates that intentionally decreasing eccentric velocity increases total TUT and may provide a better mechanical and physiological environment that encourages muscle growth compared to faster eccentric speeds when concentric speed is equal.

These findings agree with previous authors who have stated that eccentric muscle actions play a larger role than concentric action for increasing skeletal muscle hypertrophy (Bird *et al.* 2005; Gumucio *et al.* 2015; Roig *et al.* 2009; Schoenfeld, Ogborn, Vigotsky, Franchi, & Krieger, 2017). Furthermore, some authors (Gehlert *et al.* 2015; Roig *et al.* 2009) provided evidence

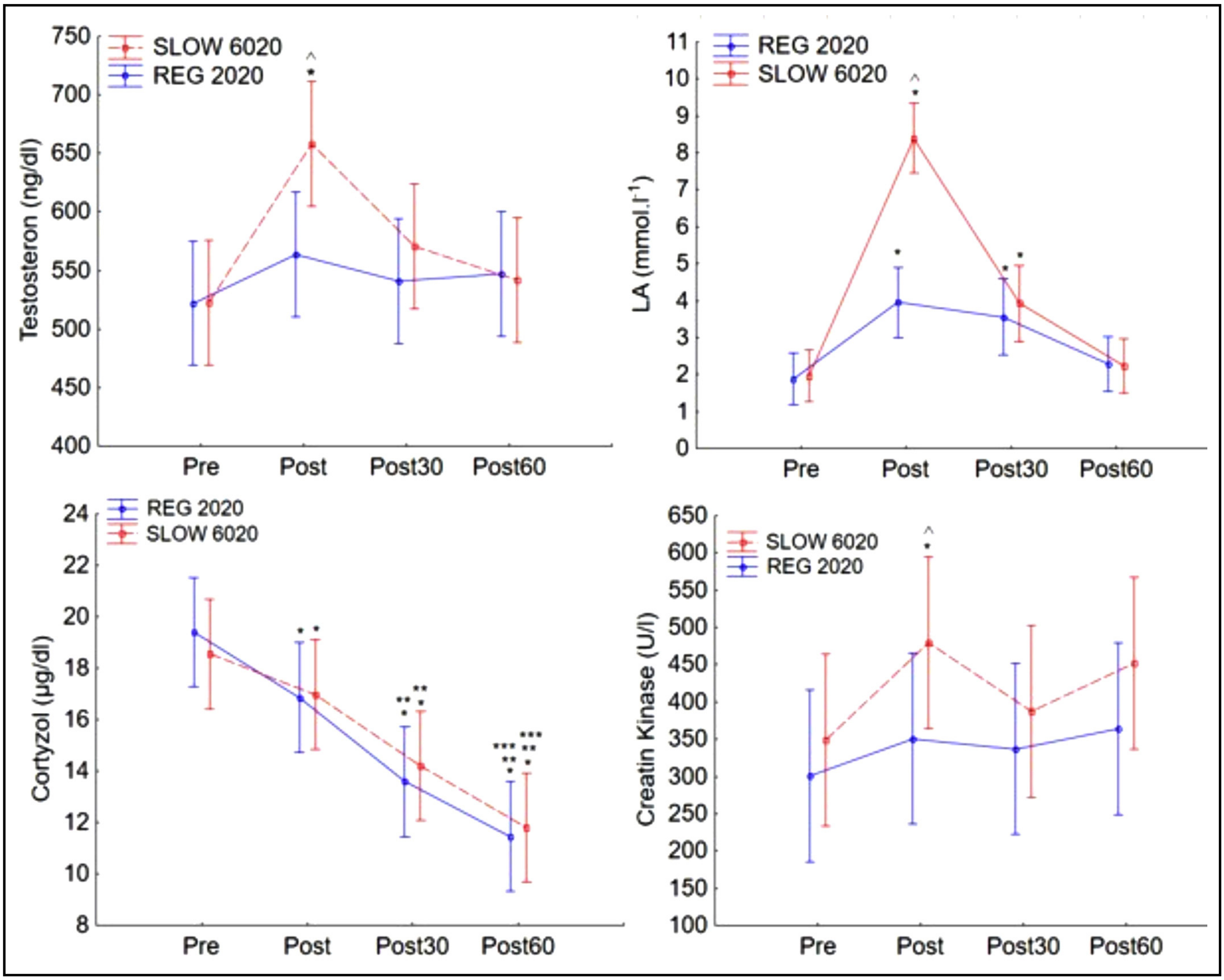

Fig. 3. Biomarkers before and after exercise

Legend: REG = exercise protocol at regular tempo 2020, SLOW = exercise protocol with slow eccentric contraction 6020, LA = lactate, A = testosterone result, B = LA result, C = cortyzol result, D = creatine kinase result, * significantly greater than Pre, ** significantly greater than Post 30, *** significantly greater than Post 60, ^ significantly greater than same time point in REG.

that relatively high intensity of exercise is important for muscle hypertrophy where super slow tempo is highly decreasing lifted load.

Resistance training focused on hypertrophic development is typically accompanied by increased concentrations of LA, T, and other such as growth hormone. Previous studies presented numerous resistance protocols, after which was find the increase of LA and T (Ahtiainen, Pakarinen, Alen, Kraemer, & Häkkinen, 2003; Crewther *et al.* 2008; Kraemer *et al.* 1990; Uchida *et al.* 2009). Our study indicates that lengthening the time of eccentric actions increases post-exercise LA and T concentrations in comparison to “regular” eccentric speeds. Previous research has shown that increasing concentric TUT (2/0/4/0 vs 2/0/2/0) does not affect post-exercise T, LA, or C levels (Headley *et al.* 2011), but increasing total TUT results in increased concentrations of T and LA (Kraemer *et al.* 1990). Therefore, as increasing only concentric TUT does not seem to positively affect the physiological response, but increasing total TUT does, it seems as though eccentric TUT plays the largest role in acute physiological responses to exercise.

Our result that SLOW protocol had higher CK support the idea that SLOW might be more effective for muscle hypertrophy than REG. Muscle hypertrophy has been linked to exercise-induced muscle damage, which is often identified by increased CK levels (Brancaccio, Maffulli, & Limongelli, 2007; Ebbeling & Clarkson, 1989). The exercise-induced muscle damage is also dependent of exercise volume, where our study included only 5set in trained individual. Therefore, the increased values of muscle damage markers after SLOW protocol might show that SLOW protocol stimulates the hypertrophy even if low total volume of exercise is used.

Although some studies have shown that C increases immediately post exercise (Ahtiainen *et al.* 2003; Uchida *et al.* 2009), other studies do not (Flegr *et al.*

2012; Headley *et al.* 2011; Smilios *et al.* 2003; Tufano *et al.* 2017). Also, most studies show that 30 min after exercise, C tends to decrease (Kraemer & Ratamess, 2005), which is in line with our findings. Moreover, the C level should positively correlated with LA production (Kraemer & Ratamess, 2005), where our study find increased LA production only. On the other hand, the chronic response for training protocol in C level is very individual (Kraemer & Ratamess, 2005), where some other studies reported increased T and no change in C after resistance training (Headley *et al.* 2011; Smilios *et al.* 2003; Tufano *et al.* 2017), after hypertrophy protocol 10sets with 75% of 1-RM (Crewther *et al.* 2008) or C level even decreased after maximum strength training protocols (da Conceição *et al.* 2014; McCaulley *et al.* 2009). Therefore, the low C response might be the cause of athletes high strength level, where 5sets performed during exercise protocol did not elicit high C release although other biochemical markers associated with hypertrophy increased. The increased T response paired with decreased post-exercise C levels might mean that the mechanical stress provided during SLOW protocol most likely favored anabolism over catabolism.

Some may question the importance of acute changes in LA, T, C, and CK for long-term skeletal muscle hypertrophy (Ahtiainen *et al.* 2003), but a large body of evidence supports the importance of acute physiological responses to exercise (Kraemer & Ratamess, 2005; Smilios *et al.* 2003). Therefore, we believe that the present data indicates that alterations to eccentric TUT likely play a role in the development of skeletal muscle hypertrophy. Although this study did not evaluate the chronic effects of SLOW and REG on muscle growth, the present data is promising, and future researchers should investigate the efficacy of SLOW in a training environment. Specifically, future research should investigate the effect of cadence on different exercises that utilize large muscle groups and larger displacements such as squats, deadlifts, leg press, lat pull downs, and the like, as lengthening the contraction phases during multiple exercise may decrease total exercise volume (Hatfield *et al.* 2006; Roig *et al.* 2009), reaching a point of diminishing returns. Another restrain in is the use of BP exercise only, which require the use of relatively small amount of muscle mass and small displacement compared to other exercises like squats or leg press. The BP exercise has been selected to be comparable to previous studies (Hatfield *et al.* 2006; Headley *et al.* 2011) and because it is widely used resistance exercise in different training protocols, and in which the speed of motion influence the BP performance, muscle activity and contribution of all loading parameters (Maszczyk *et al.* 2016; Stastny *et al.* 2017). Because the BP exercise in eccentric action might be the cause of joint block (Gołaś *et al.* 2017; Panska *et al.* 2016; Piglova *et al.* 2017), we used the flat BP variation for safety reasons. We assume that different exercises like squats or pull ups might require different exercise tempo to elicit similar training response. Especially, when using Squats or leg press, the bigger extension of eccentric contraction might be more effective that our 6s eccentric protocol. Our results have been performed on resistance trained men, therefore our finding should be transferred to another population such as woman (Gillies, Putman, & Bell, 2006) or untrained men (Chapman, Newton, Sacco, & Nosaka, 2006) with caution.

Practical application

The SLOW protocol (6/0/2/0) may be more effective than REG (2/0/2/0) for muscle growth when using the BP exercise for multiple sets performed to failure. The SLOW protocol should be used in training session aiming to reach high LA production, testosterone boost and muscle damage in resistance trained athlete using sufficiently high exercise intensity (70% of 1 RM) and might improve the movement stability. The use of slow tempo exercise is effective for increased hormonal response and TUT extension, when only eccentric phase of movement is prolonged. However, it is important to note that the subjects in the present study were well-trained and the protocol involved only a single exercise. Therefore, caution should be used when applying a 6/0/2/0 cadence across multiple exercises, in the long term, in less-trained populations.

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