The effects of resistance training experience on movement characteristics in the bench press exercise

AUTHORS: Adam Maszczyk[1], Michał Wilk[1], Michał Krzysztofik[1], Mariola Gepfert[1], Adam Zając[1], Miroslav Petr[2], Petr Stastny[2]

[1] Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland
[2] Charles University in Prague, Faculty of Physical Education and Sport, Czech Republic

Corresponding author:
Michał Wilk
Institute of Sport Sciences, The
Jerzy Kukuczka Academy of
Physical Education
Mikolowska Str. 72A
40-065, Katowice
Poland
Phone: +48 606 289 498
E-mail: m.wilk@awf.katowice.pl

ABSTRACT: The main aim of this study was to determine whether the level of experience in strength training has a significant effect on differences in the value of exercise volume determined on time under tension (TUT) and number of repetition (REP) for a specific movement tempo. The study examined 68 men divided into groups of beginners and advanced strength trained athletes. The participants performed 5 sets of bench press (BP) at 70% 1RM using either a REG, MED or SLOW metronome guided cadence. Each set was performed to failure and with 3 min of rest between sets. Significant differences in TUT were found between the groups of beginners and advanced athletes for the slow (SLO) 6/0/4/0 tempo in set 1 (p = 0.01) and set 2 (p = 0.04), and for the regular (REG) 2/0/2/0 tempo in set 5 (p = 0.01). Significant differences were documented for total TUT between the beginners and advanced athletes for the SLO 6/0/4/0 tempo (p = 0.04). The results of ANOVA revealed significant differences in the number of repetitions between groups for the SLO 6/0/4/0 tempo in set 4 (p = 0.04) and set 5 (p = 0.04), and for the REG 2/0/2/0 tempo in set 5 (p = 0.01). The main finding of this study is that strength training experience has a significant effect on training volume, both in terms of TUT and REP at a specific constant movement tempo. Significant differences do not occur for each value of the tempo used.

INTRODUCTION

Strength training is one of the most popular forms of physical activity. Physical exercise with external loads can be used at almost any age, by young people and older adults, people with training experience and beginners. Regardless of who performs the physical exercise, programming training loads is connected with determination of the volume and intensity of exercise. Volume and intensity of training depend on individual components of strength training, with each component having both, acute and chronic effects on adaptation [1]. Principal variables of resistance training include the value of external load, often synonymous with intensity (%1RM), number of repetitions, sets, duration of rests intervals between sets [2–4]. More and more often, the examinations related to strength training analyse the impact of movement tempo in resistance training on exercise volume, increase in muscular strength and power or hypertrophy [5–13]. The term tempo relates to the rate at which each repetition is performed. Movement tempo and cadence are most often defined by means of several digits which correspond to individual movement phases. For example, 6/0/3/0 denotes a 6-second eccentric phase, no break in the transition phase, a 3-second concentric phase and no rest before the next repetition [8]. Changes in tempo, and consequently, the velocities in individual phases of the movement, can results 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 [9] or conscious control of individual movement cadences, which has been the topic of recent research [12]. Tempo, i.e. duration of a single repetition, determines time under tension (TUT) for a set and, in total, for a training session [12]. The TUT value for a particular exercise has an effect on exercise volume and the value of post-exercise metabolic and endocrine adaptations [2,13]. Exercise volume represents one of the most critical elements of the adaptation process, not only in regards to muscular strength, but also in the development of other motor abilities. In strength training, exercise volume has been evaluated based on the number of repetitions or, as suggested by Wilk et al. [12], based on the TUT values. A study by Wilk et al. [12] showed that the change in movement tempo in strength training impacts significantly on the volume of exercise, both in terms of the number of completed REP and TUT values. Movement tempo in strength training also determines the value of generated muscle force [4,11,14] and number of repetitions that can be completed in a set [10,12,13]. Furthermore, slow movement tempo leads to higher post-exercise fatigue and a greater decline in muscle power compared to volitional tempo [5]. These findings show that slower movement tempo and, consequently, potentially lower exercise volume (if it is defined based on REP)

can place a greater load on the human body compared to training with conventional movement tempo and greater training volume (REP). However, if training volume is defined according to the guidelines by Wilk et al. [12,13] based on TUT, the use of slow movement tempo allows the athlete to significantly extend TUT and, consequently, increase training volume. Longer time of sustained muscle tension in a set can be also useful in evoking muscle hypertrophy [15,16] which can be linked to e.g. the fact that slow movement extends the time under tension without the relaxation phase [17,18]. Some previous studies showed also that maximal power production depends on training status [19] and motivation state [20].

All previous studies that have analysed the effect of movement tempo or cadence of individual movement phases on the level of acute or chronic adaptations focused on the analysis of a specific homogenous research group. However, training effects depend not only on the value of particular training variables, including movement tempo, but also on the experience of the people who perform the resistance training programs. Since previous studies have confirmed that movement tempo impacts exercise volume significantly, the number of completed REP, time under tension (TUT) and levels of muscle force and power [4,5,10–14] in this study we attempted to verify whether there are significant differences in exercise volume evaluated based on TUT and REP for specific movement tempo between novice and advanced strength trained subjects. To date, it has not been demonstrated whether the level of response at constant movement tempo is the same in groups of beginners and advanced strength trained subjects.

MATERIALS AND METHODS

All testing was performed in the Strength and Power Laboratory 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 concentric 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 examinations before expressing their written consent for participation in the study.

Study participants

The study examined 68 men divided into groups of beginners and advanced strength trained athletes. The novice group included 32 men (18–32 yrs, 69.9 ± 5.7 kg, 67.3 ± 6.9 kg bench press 1RM). Before the examinations, the novice group was trained in terms of bench press technique and performed three strength training sessions in two weeks prior to the examinations dedicated to the bench press technique with a specific movement tempo. The advanced group comprised of 36 men, (20–38 yrs, 81.2 ± 6.7 kg, 112.3 ± 12.5 kg bench press 1RM) with a minimum of two years of strength training experience (3.7 ± 0.92 years). All subjects were over 18 years old. 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 at the Academy of Physical Education in Katowice, Poland, 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 experiment.

Procedures

Familiarization session and one repetition maximum test

The participants arrived at the laboratory at the same time of day as the upcoming experimental sessions (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, followed by
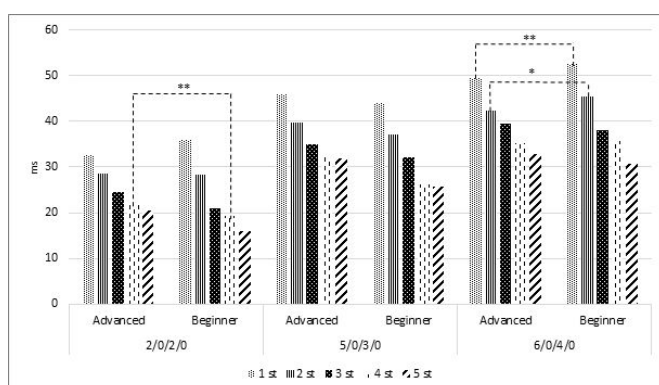

FIG. 1. TUT for 2/0/2/0, 5/0/3/0 and 6/0/4/0 tempos in sets 1–5 between beginner and advanced groups.

Note: ** p< .01, *p<.05

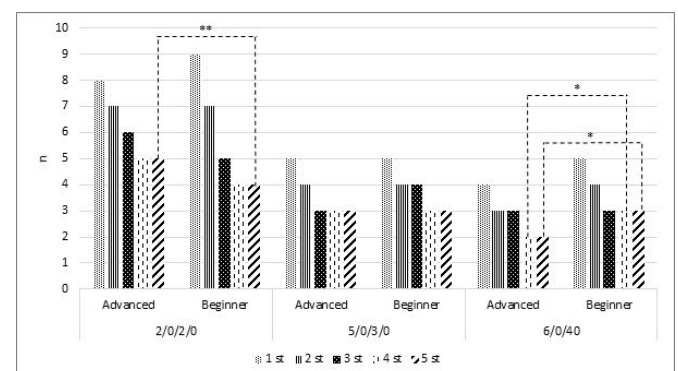**FIG. 2.** REP for 2/0/2/0, 5/0/3/0 and 6/0/4/0 tempos in sets 1–5 between beginner and advanced groups.

Note: ** p< .01, *p<.05

a general upper body warm-up of 10 body weight pull ups and 15 body weight push-ups. Next, the participants 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 81-cm mark on 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 a 5 min rest interval 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). After completing the same warm-up as in the previous session, the participants performed 5 sets of BP at 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 the statistical analyses were performed using the STATISTICA software version 12 (StatSoft, Inc.) at $\alpha = .0.05$. The data were tested for normal distribution using the Shapiro-Wilk test. In order to establish whether the differences occurred for the number of repetitions and TUT between the beginner group and advanced athletes for the REG 2/0/2/0, MED 5/0/3/0 and SLO 6/0/4/0 tempos and series 1–5, the analysis of variance (ANOVA) was performed and post-hoc Tukey's tests were continued. The F statistic and level of significance were evaluated. Homogeneity of variance was verified and met using the Levene's test at $p > 0.05$.

RESULTS
The data had a normal distribution (W range between 0.80 and 0.99). Significant differences in TUT were found between the groups of beginners and advanced athletes for the SLO 6/0/4/0 tempo in set 1 ($p = 0.01$) and set 2 ($p = 0.04$), and for the REG 2/0/2/0 tempo in set 5 ($p = 0.01$) (Table 1 and Table 3, Figure 1). Furthermore, significant differences were documented for total TUT between the beginners and advanced athletes for the SLO 6/0/4/0 tempo ($p = 0.04$) (Table 3). The ANOVA also revealed significant differences in the number of repetitions between groups for the SLO 6/0/4/0 tempo in set 4 ($p = 0.04$) and set 5 ($p = 0.04$), and for the REG

TABLE 1. TUT in particular sets of the BP for REG 2/0/2/0, MED 5/0/3/0 and SLO 6/0/4/0 tempos in the beginner and advanced groups.

Set	Advanced			Beginner		
	2/0/2/0	5/0/3/0	6/0/4/0	2/0/2/0	5/0/3/0	6/0/4/0
1st	32.52 (±8.10)	45.95 (±15.62)	49.53 (±17.02)**	35.85 (±9.18)	43.88 (±15.44)	52.53 (±10.19)**
2nd	28.52 (±8.50)	39.80 (±16.21)	42.41 (±17.19)*	28.30 (±7.50)	37.11 (±8.25)	45.39 (±10.53)*
3rd	24.43 (±7.02)	34.90 (±17.00)	39.41 (±17.77)	20.90 (±5.78)	32.17 (±7.33)	38.17 (±6.88)
4th	21.61 (±7.48)	32.15 (±17.61)	35.29 (±18.54)	19.25 (±4.70)	26.17 (±6.35)	35.61 (±5.93)
5th	20.41 (±6.22)**	31.80 (±17.75)	32.76 (±19.17)	15.90 (±5.04)**	25.78 (±8.34)	30.72 (±3.41)

Note: ** p< .01, *p<.05

TABLE 2. REP in particular sets for each 2/0/2/0, 5/0/3/0 and 6/0/4/0 tempos in the beginner and advanced groups.

Set	Advanced			Beginner		
	2/0/2/0	5/0/3/0	6/0/4/0	2/0/2/0	5/0/3/0	6/0/4/0
1st	8 (±2)	5 (±1)	4 (±1)	9 (±2)	5 (±1)	5 (±1)
2nd	7 (±2)	4 (±1)	3 (±1)	7 (±1)	4 (±1)	4 (±1)
3rd	6 (±1)	3 (±1)	3 (±1)	5 (±1)	4(±1)	3 (±1)
4th	5 (±1)	3 (±1)	2 (±1)*	4 (±1)	3 (±1)	3 (±1)*
5th	5 (±1)**	3 (±1)	2 (±1)*	4 (±1)**	3 (±1)	3 (±1)*

Note: ** p< .01, *p<.05

TABLE 3. Total TUT for particular 2/0/2/0, 5/0/3/0 and 6/0/4/0 tempos in the beginner and advanced groups

Total TUT	Group		Anova	
	Advanced	**Beginner**	**F**	**p**
2/0/2/0	124 (±33)	123 (±28)	0.02	0.89
5/0/3/0	166 (±29)	166 (±31)	0.01	0.99
6/0/4/0	178 (±33)	203.8 (±33.9)	*4.76*	*0.04*

TABLE 4. Total REP for particular 2/0/2/0, 5/0/3/0 and 6/0/4/0 tempos in the beginner and advanced groups

Total REP	Group		Anova	
	Advanced	**Beginner**	**F**	**P**
2/0/2/0	28 (±7)	28 (±6)	0.02	0.89
5/0/3/0	18 (±4)	18 (±3)	0.26	0.61
6/0/4/0	15 (±4)	17 (±4)	2.19	0.15

2/0/2/0 tempo in set 5 ($p = 0.01$) (Table 2 and Table 4, Figure 2). The total number of repetitions for individual REG 2/0/2/0, MED 5/0/3/0 and SLO 6/0/4/0 tempos did not differ significantly between groups ($p > 0.05$) (Table 4).

DISCUSSION

The main finding of the study is that the level of strength training experience has a significant effect on training volume both in terms of TUT and REP at a specific constant movement tempo. However, significant differences in TUT_{sum1-5} between BEG and ADV were found only for the SLO tempo (Table 3). Contrary to TUT_{sum1-5} values, no significant difference was demonstrated for REP_{sum1-5} between the BEG and ADV groups (Table 4). These findings are consistent with the guidelines discussed in a study by Wilk et al. [12], thus confirming the usefulness of determination of exercise volume by means of TUT rather than REP only. Duration of a single repetition i.e. total duration of concentric and eccentric cadences and duration of isometric rest pauses between phases is determined by the speed at which the repetition is performed [6,8]. TUT determines the volume of work performed more accurately than REP, which is especially noticeable in case of slower movement tempos. In the present study, the duration of one repetition with the SLO tempo was 10 seconds, whereas the point of maximal muscle fatigue (MMF) could occur at any moment of the exercise, which could be determined only by TUT rather than REP. In case of the analysis of the volume based on REP values, failure to perform a repetition, even if 8–9 second work was performed within the 10-second movement tempo led to the lack of recording the repetition as a measure of exercise volume, which substan-

tially limits the reliability of such measurements. In case of TUT, the number of the seconds of work is recorded for the instant of actual exhaustion, regardless of the phase and moment of performing the movement. The legitimacy of the evaluation of exercise volume based on the duration of the TUT_{set} or TUT_{sum} as a value of the total muscle contraction for the exercise and entire training session, respectively, concerns any value of tempo. However, the slower the movement tempo and cadence, the higher differences between TUT and REP variables. A significant difference was demonstrated in values of TUT_{sum1-5} between BEG and ADV groups. Interestingly, the ADV group obtained a lower value of TUT_{sum1-5} 178s (±33) compared to the BEG group, TUT_{sum1-5} 203.8s (±33.9) (Table 3). Higher TUT values in the BEG group are likely to be linked to the ratio of FT/ST muscle fibres involved in the exercise. Adaptations resulting from strength training lead to transformation of muscle fibres [15,16,21–23]. The most intensively growing fibres are of type II, with high number of myofibrils, which are characterized not only by greater contraction force but also lower susceptibility to fatigue [16]. Type I muscle fibres are characterized by aerobic metabolism, low contraction force and high resistance to fatigue. These fibres to not react well to resistance training, and show limited hypertrophy. Advanced strength trained subjects are characterized by greater percentage of type IIa and IIb muscle fibres compared to beginners. A higher percentage of type IIa and type IIb fibres during resistance training in advanced athlete, especially in SLO tempo, impacts muscle contraction recorded during exercise, which is related to the level of metabolic stress leading to MMF. Combined with changed concentrations of hydrogen ions and deficiency of adenosine triphosphate (ATP), the increased concentration of metabolic products is directly related to the achieved TUT. This was especially noticeable for SLO tempo in the ADV group, which is consistent with the findings published by Hatifield et al. [5], who showed that slow movement tempo leads to higher muscle fatigue, analysed both, based on the level of muscle power and self-reported exhaustion of study participants. In case of the SLO tempo, significant difference in TUT_{sum1-5} was caused in particular by the differences in TUT_{set1} and TUT_{set2} (Figure 1). Greater value of TUT_{set1} TUT_{set2} in the BEG group compared to ADV can be linked, similar to TUT_{sum1-5} to the ratio of muscle fibre types, with the dominance of IIa and IIb fibres in the ADV compared to the BEG group. The results, with particular focus on differences in TUT_{set1}, TUT_{set2} and TUT_{sum1-5} for SLO tempo, are consistent with previous reports which have indicated that slower movement tempo impacts on training volume and intensity [5,11–14]. TUT_{set3-5} did not show significant differences between the BEG and ADV groups, which is likely to be related to the fact that metabolic exhaustion was observed and post exercise metabolites were accumulated in both the BEG and in ADV groups in TUT_{set1} and TUT_{set2}, thus limiting exercise capacity in the next sets of the experiment. Exhaustion at this level of exercise can be assumed to be equivalent in the BEG and ADV groups. In case of REG

tempo, significant changes in TUT were found only in TUT_{set5}, where BEG group was able to perform the bench press with 2/0/2/0 tempo for a significantly longer duration compared to the ADV group. The significance of the TUT_{set5} difference did not impact on TUT_{sum1-5}. The study did not find significant differences in TUT_{sum1-5} for the REG and MED tempos, which can indicate that only the exercise using extremely slow tempo differentiate the value of exercise volume depending on the level of experience in resistance training.

CONCLUSIONS

Significant differences in TUT_{sum1-5} in the case of SLO tempo may suggest that the slower the movement tempo or cadence of particular movement phases, the less pronounced the differences resulting from the level of experience in resistance training. In case of REP,

the tests did not show significant differences in REP_{sum1-5} in any of the analysed movement tempos. This is consistent with the suggestion by Wilk et al. [12] who indicated that the value of TUT is a more accurate determinant of exercise volume compared to REP. Significant differences in TUT_{sum1-5} and TUT_{set} both for the SLO and REG tempos confirm that both movement tempo [12] and level of experience in strength training influence exercise volume.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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