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Impact of Movement Tempo Distribution on Bar Velocity During a Multi-Set Bench Press Exercise

by

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The goal of the present study was to evaluate the effect of contrast tempo movement on bar velocity changes during a multi-set bench press exercise. In randomized and counter-balanced order, participants performed three sets of the bench press exercise at 60%1RM under two testing conditions: E-E where all repetitions were performed with explosive (X/0/X/0) movement tempo; and S-E where the first two repetitions were performed with a slow tempo (5/0/X/0) while the third repetition was performed with explosive movement tempo (slow, slow, explosive). Twelve healthy men volunteered for the study (age = 30 ± 5 years; body mass = 88 ± 10 kg; bench press 1RM = 145 ± 24 kg). The three-way repeated measures ANOVA (tempo × set × repetition) showed statistically significant multi-interaction effect for peak bar velocity (p < 0.01; η2 = 0.23), yet not for mean bar velocity (p = 0.09; η2 = 0.14). The post hoc results for multi-interaction revealed that peak bar velocity in the 3rd repetition was significantly higher for E-E compared to S-E only during set 1 (p < 0.001). Therefore, the distribution of movement tempo had a significant impact on peak bar velocity, but not on mean bar velocity. The decrease in peak bar velocity in the 3rd repetition during the S-E condition was observed only in the first set, while such a tendency was not observed in the second and third set.

Key words: duration of movement, contrast tempo, slow movement, time under tension.

Introduction

The tempo of movement of particular repetitions during resistance exercise is a training variable which has a significant impact on the acute responses and chronic adaptive changes following resistance training (Davies et al., 2017; Schoenfeld et al., 2015; Wilk et al., 2019, 2020a). In training practice, there are two types of movement tempo during resistance training: unintentional and intentional. An unintended tempo of movement occurs when the duration of the repetition is not controlled. In such cases, the actual duration of movement, especially in the concentric phase, depends on the load used or the appearance of fatigue symptoms, where an increased load or increased fatigue causes the extension of the duration of movement tempo (Suchomel et al., 2019; Wilk et al., 2019, 2020a). Intentional movement tempo occurs during conscious control of the duration of the movement. However, intentional movement tempo can be purposefully used when the load is light enough to control it, and fatigue does not influence one's ability to control the duration of a repetition (Suchomel et al., 2019). Intentional tempo of movement should be specified using a sequence of four-digits which describe: the eccentric, isometric/transition, concentric, and isometric/transition phases (Wilk et al., 2019, 2020a). For example, 5/0/2/0 denotes a 5 s eccentric phase, no intentional isometric pause during the

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transition phase, a 2 s concentric phase, and no pause between the completion of the concentric phase and the beginning (eccentric phase) of the next repetition. Further the X (e.g., 2/0/X/0) determines maximal speed.

Although much research has examined the acute and chronic effects of different movement tempos in resistance training, previous studies have used a constant movement tempo throughout the sets or a training session (e.g. 6/0/1/0) (Munn et al., 2005; Sakamoto and Sinclair, 2006; Schoenfeld et al., 2015), and only one study assessed the acute effect of different movement tempo distribution on power output and bar velocity changes in the bench press exercise at 60% of one-repetition maximum (1RM) (Wilk et al., 2021a). Wilk et al. (2021a) showed that the peak power output and peak bar velocity in the last, 3rd repetition of a set were significantly higher for a condition where the first two repetitions were performed with an explosive tempo compared to the condition where the first two repetitions were performed with a slow movement tempo (5/0/X/0). However, when only one slow repetition was used at the beginning of a set, there was no decrease in power output nor bar velocity in the 3rd repetition. Furthermore, Wilk et al. (2021a) did not show a significant impact of different tempo distribution on mean power output and mean bar velocity. Despite that the fact that Wilk et al. (2021a) were the first to introduce and investigate the contrast movement tempo (fast vs. slow), the results of that study were based only on one set, while true resistance training in trained individuals rarely contains only one set of a particular exercise.

Fast or explosive movement tempo is generally used to generate high power out-put levels what is particularly significant for numerous sport disciplines (Fielding et al., 2002; Neils et al., 2005; Bottaro et al., 2007). However, the American College of Sports Medicine (2009) recommended that for the inter-mediate sports level, moderate tempos should be used, while for advanced athletes, a variety of tempos, from explosive and fast to slow and super slow tempos should be employed. The combination of different tempos for advanced training may provide most benefits for power, strength, and hypertrophy gains (Munn et al., 2005; Schoenfeld et al., 2015), whereby acute exercise responses could largely

vary depending on the tempo of movement (Sakamoto and Sinclair, 2006; Wilk et al., 2020a). Therefore, due to the fact that Wilk et al. (2021a) showed that different movement tempo distribution had a significant effect on peak bar velocity changes, but not on mean bar velocity changes in a single set, the goal of the present study was to evaluate the effect of contrast tempo movement on bar velocity changes during a multi-set resistance exercise. It was hypothesized that contrast tempo would significantly affect bar velocity during the bench press exercise.

Methods

The main aim of the study was to evaluate the effect of different movement tempo distribution on bar velocity changes during a multi-set bench press exercise at 60%1RM. In randomized and counter-balanced order, participants performed two training sessions consisting of 3 sets of 3 repetitions with different tempo: E-E where all repetitions were performed with explosive (X/0/X/0) movement tempo; and S-E where the first two repetitions were performed with a slow tempo (5/0/X/0) while the third repetition was performed with explosive movement tempo (slow, slow, explosive; Wilk et al., 2021a). All testing sessions were conducted in the Strength and Power Laboratory at the Academy of Physical Education in Katowice, Poland and in Gdansk University of Physical Education and Sport, Poland.

Participants

Twelve healthy men volunteered for the study (age = 30 ± 5 years; body mass = 88 ± 10 kg; experience in resistance training = 10 ± 5 years; bench press 1RM = 145 ± 24 kg). The following inclusion criteria were used: a) 1RM bench press of at least 120% of own body mass, b) no musculoskeletal injuries prior to the examination. Participants were informed about the benefits and potential risks of the study and gave written informed consent to participate in the study. The study protocol was approved by the Bioethics Committee for Scientific Research, at the Academy of Physical Education in Katowice, Poland (10/2018), and all procedures were in accordance with the latest version of the Declaration of Helsinki. To calculate the sample size, statistical software (G*Power, Dusseldorf, Germany) was used. Given the applied 3-way

analysis of variance (ANOVA) (2 conditions and 9 repeated measures; [3 sets and 3 repetitions]), a small overall effect size (ES) = 0.3, an alpha-error < 0.05, the desired power (1-ß error) = 0.8 and correlation among repeated measures = 0.85, the total sample size resulted in six participants.

Procedures

Familiarization Session

Two weeks before the main experiment, participants performed a familiarization session. First, participants completed a general upper body warm-up, followed by a specific bench press warm-up sets performed at a load of 20 and 40% of their estimated 1RM. After the warm-up, the familiarization session began. During the familiarization session, each participant performed 2 sets (one set for each tempo E-E; S-E) of 3 repetitions of the bench press at a load of 50% of their estimated 1RM.

Bench press 1RM Strength Test

One week before the main experiment the 1RM bench press test was performed as described elsewhere (Wilk et al., 2021a). During the 1RM test session, the general upper body warm-up was the same as during the familiarization session. Afterwards, participants performed specific bench press warm-up repetitions at a load of 20, 40, and 60% of their estimated 1RM. The first testing load was set to estimated 80%1RM and was increased by 2.5 to 10 kg for each subsequent trial. This process was repeated until failure. During the 1RM test, participants executed one repetition with volitional movement tempo. The rest interval between successful sets was 5 min. Grip width on the bar was set at 150% of the individual bi-acromial distance, and this was used for all main attempts and all experimental sessions.

Experimental Sessions

In randomized and counter-balanced order, participants performed three sets of the bench press exercise at 60%1RM under two testing conditions. During each condition, a different tempo distribution was used: condition E-E where all repetitions were performed with explosive (X/0/X/0) movement tempo (explosive, explosive, explosive); condition S-E where the first two repetitions were performed with a slow tempo (5/0/X/0), while the third repetition was performed with explosive movement tempo (slow, slow, explosive). A Tendo Power Analyzer system (Tendo Sport Machines, Trencin, Slovakia)

was used for the evaluation of bar velocity. Measurements were made independently for each repetition and automatically converted into values of peak bar velocity and mean bar velocity.

Statistical Analysis

All statistical analyses were performed using Statistica 9.1. Results are presented as means with standard deviations. The Shapiro-Wilk, Levene and Mauchly´s tests were used in order to verify the normality, homogeneity and sphericity of the sample data variances, respectively. To evaluate differences in bar velocity between E-E and S-E conditions three-way ANOVA (2 conditions × 3 sets × 3 repetitions) was used. Due to the fact that under the S-E condition one or two repetitions were performed with intentional slow movement tempo, which directly affected the result of bar velocity, to evaluate bar velocity difference only during the third repetition between the E-E and S-E conditions we used a two-way ANOVA (2 conditions × 3 sets). The statistical significance was set at $p < 0.05$. The effect size was determined by partial eta squared ($\eta2$). Partial eta squared values were classified as small (0.01 to 0.059), moderate (0.06 to 0.137) and large (>0.137). In the event of statistically significant main effect, the Tukey's test was conducted to locate the differences between mean values. Parametric effect sizes (Cohen's d) were defined as: large (g > 0.8); moderate (g between 0.8 and 0.5); small (g between 0.49 and 0.20) and trivial (g < 0.2). Percent changes with 95% confidence intervals (95CI) were also calculated.

Results

The three-way repeated measures ANOVA showed statistically significant multi-interaction (tempo × set × repetition) effect for peak bar velocity ($p < 0.01$; $\eta2 = 0.23$) and not for mean bar velocity ($p = 0.09$; $\eta2 = 0.14$). Furthermore, the three-way repeated measures ANOVA showed statistically significant main condition (tempo) effect for peak bar velocity ($p < 0.01$; $\eta2 = 0.49$) and not for mean bar velocity ($p = 0.30$; $\eta2 = 0.10$). The post hoc results for multi-interaction are shown in Table 1. The post hoc results for main condition (tempo) effect revealed that peak bar velocity was significantly higher for E-E when compared to the S-E condition ($p < 0.01$).

The two-way repeated-measures ANOVA performed only between the 3rd repetitions showed a statistically significant interaction effect for peak bar velocity ($p = 0.01$; η2 = 0.24), yet not for mean bar velocity ($p = 0.24$; η2 = 0.11). The post hoc analysis for interaction revealed that peak bar velocity in the 3rd repetition for set 1 was significantly higher for the E-E compared with to the S-E condition ($p < 0.01$; Table 2). Post hoc analysis for interaction revealed that peak bar velocity in the 3rd repetition for S-E condition was significantly higher in set 2 and set 3 when compared to set 1 ($p = 0.01$, $p <0.01$, respectively; Table 2). The two-way repeated-measures ANOVA did not show a statistically significant main effect of condition for peak bar velocity ($p = 0.30$; η2 = 0.10) and for mean bar velocity ($p = 0.78$; η2 = 0.02).

Table 1

A comparison of bar velocity variables for all repetitions during three movement tempos.

Condition	Set 1			Set 2			Set 3		
	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Peak Bar Velocity [m/s]									
E-E	0.78 ± 0.12 (0.71 to 0.86)	0.79 ± 0.12 (0.71 to 0.87)*	0.81 ± 0.13 (0.73 to 0.89)*	0.84 ± 0.13 (0.76 to 0.93)*	0.82 ± 0.14 (0.74 to 0.91)*	0.81 ± 0.11 (0.74 to 0.88)	0.85 ± 0.13 (0.77 to 0.94)*	0.85 ± 0.09 (0.79 to 0.90)*	0.83 ± 0.10 (0.77 to 0.90)
S-E	0.75 ± 0.14 (0.66 to 0.84)	0.71 ± 0.13 (0.63 to 0.79)*	0.74 ± 0.15 (0.65 to 0.84)*	0.76 ± 0.11 (0.69 to 0.83)*	0.73 ± 0.12 (0.65 to 0.81)*	0.79 ± 0.16 (0.69 to 0.90)	0.77 ± 0.13 (0.69 to 0.85)*	0.71 ± 0.12 (0.63 to 0.79)*	0.80 ± 0.17 (0.70 to 0.91)
Mean Bar Velocity [m/s]									
E-E	0.55 ± 0.08 (0.50 to 0.60)	0.59 ± 0.09 (0.53 to 0.64)	0.60 ± 0.08 (0.55 to 0.65)	0.59 ± 0.08 (0.54 to 0.65)	0.59 ± 0.11 (0.52 to 0.66)	0.60 ± 0.08 (0.55 to 0.65)	0.60 ± 0.09 (0.54 to 0.66)	0.61 ± 0.07 (0.57 to 0.66)	0.62 ± 0.08 (0.57 to 0.67)
S-E	0.55 ± 0.09 (0.50 to 0.61)	0.55 ± 0.09 (0.49 to 0.61)	0.58 ± 0.11 (0.51 to 0.65)	0.58 ± 0.09 (0.52 to 0.63)	0.56 ± 0.08 (0.51 to 0.61)	0.61 ± 0.10 (0.55 to 0.68)	0.59 ± 0.10 (0.53 to 0.65)	0.56 ± 0.08 (0.51to 0.62)	0.63 ± 0.11 (0.56 to 0.70)

*Results are mean ± SD (95% confidence intervals). *statistically significant differences p < 0.05.*
E-E = explosive movement tempo in each repetition;
S-E = slow; slow; explosive; movement tempo for each repetition

Table 2

A comparison of bar velocity variables for the 3rd repetition during particular movement tempos.

Condition	Set 1	Set 2	Set 3
	Rep 3	Rep 3	Rep 3
Peak Bar Velocity [m/s]			
E-E	0.81 ± 0.13 (0.73 to 0.89)*	0.81 ± 0.11 (0.74 to 0.88)	0.83 ± 0.10 (0.77 to 0.90)
S-E	0.74 ± 0.15 (0.65 to 0.84) *^#	0.79 ± 0.16 (0.69 to 0.90)^	0.80 ± 0.17 (0.70 to 0.91)#
Mean Bar Velocity [m/s]			
E-E	0.60 ± 0.08 (0.55 to 0.65)	0.60 ± 0.08 (0.55 to 0.65)	0.62 ± 0.08 (0.57 to 0.67)
S-E	0.58 ± 0.11 (0.51 to 0.65)	0.61 ± 0.10 (0.55 to 0.68)	0.63 ± 0.11 (0.56 to 0.70)

** statistically significant differences between conditions in particular sets p < 0.05; ^
or # statistically significant differences between particular
sets during different conditions p < 0.05*
E-E = explosive movement tempo in each repetition;
S-E = slow; slow; explosive; movement tempo for each repetition

Discussion

The main goal of the present study was to assess the impact of different movement tempo distribution on bar velocity changes during a multi-set bench press exercise. The results showed that different distribution of movement tempo had a significant impact on peak bar velocity, but not on mean bar velocity changes. Peak bar velocity was significantly higher during the E-E when compared to the S-E condition. However, a detailed analysis showed that the significant changes for the last 3rd repetition occurred only during the first set, and such changes were not observed in sets 2 and 3. Therefore, even if the use of slow movement tempo during the first two repetitions (S-E) causes a decrease in peak bar velocity in the 3rd repetition, this negative effect applies only to the first set of resistance exercises and not to the subsequent ones. Furthermore, the different distribution of movement tempo does not change mean bar velocity between conditions.

The main purpose of a different distribution of movement tempo through the set is to assess how the first or first two slow repetitions impact bar velocity in subsequent repetitions. The results indicate that the first two repetitions performed with a slow movement tempo (5/0/X/0) decreased peak bar velocity in the 3rd repetition compared to the condition where initial repetitions were performed with maximal movement tempo, which is consistent with the results of Wilk et al. (2021a). However, such differences in peak bar velocity between S-E and E-E conditions were observed only in the first set and not in the following sets (set 2 and 3). Therefore, the different distribution of movement tempo and its impact on peak bar velocity is partially related to the number of performed sets. The lack of significant differences in peak bar velocity in the 3rd repetition during the second and third sets is surprising as the tempo distribution was the same as in the first set. However, there are no available data regarding acute bar velocity changes during a multi-set resistance exercise with contrast movement tempo, which limits the possibility of comparing our results with other studies. The lack of negative impact of the first two slow repetitions on peak bar velocity in the 3rd repetition observed in sets 2 and 3, can be related to the effect of post-activation performance enhancement (PAPE)

(Krzysztofik et al., 2020a; Wilk et al., 2021b). PAPE is a muscle phenomenon which causes an increase in maximal velocity of movement due to a prior muscle activation (Krzysztofik et al., 2020b). The beneficial effect of PAPE on bar velocity changes was also observed between successive sets of the bench press exercise (Wilk et al., 2020b). Furthermore, Wilk et al. (2020b) showed that the PAPE effect occurred between successive sets also when the eccentric movement was performed with a slow movement tempo (6/0/X/0), which is consistent with peak bar velocity changes between sets observed under the S-E condition. A significant increase in peak bar velocity was observed in set 3 compared to set 1 and set 2, while such changes were not observed under the E-E condition. Therefore, it seems that the lack of significant differences in peak bar velocity for the 3rd repetition during the second and third sets between conditions may be related to the more effective use of the PAPE effect during S-E compared to the E-E condition.

According to Golas et al. (2016) and Morales-Artacho et al. (2015), the optimal load to induce the PAPE effect should be greater than 60%1RM, however, in this study we used a load of 60%1RM. Furthermore, it has been documented that in stronger individuals (as in this study) higher external loads are necessary (70–93%1RM) to induce the PAPE effect (Lowery et al., 2012). Therefore, the lack of the PAPE effect between sets for the E-E condition can be related with insufficient external loading. On the contrary, when the first two repetitions were performed with slow movement tempo, this load was sufficient to induce the PAPE effect in subsequent sets. Therefore, it can be assumed that the relationship between the load and volume can be an important factor inducing the PAPE effect (Seitz and Haff, 2016; Wilson et al., 2013). A recent study has indicated that not only the number of repetitions performed, but also the time under tension is an important indicator of exercise volume (Wilk et al., 2020a). Therefore, when the external load is insufficient to induce the PAPE effect as it was observed under the E-E condition, the slow movement during the eccentric phase of the bench press in an initial set increases time under tension (despite an insufficient external load), and may enhance muscle activation, muscle tension and alter fiber recruitment (Burd et al.,

2012; Martins-Costa et al., 2016; Wilk et al., 2019, 2020a) which can indirectly induce the PAPE effect. Therefore, when the external load is insufficient to induce the PAPE effect, the slower movement tempo during initial repetitions or the initial set probably provides an appropriate stimulus to induce the PAPE effect. A similar relationship between the external load used and time under tension was observed for hypertrophy responses. The greater (Tanimoto et al., 2008) or comparable (Tanimoto and Ishii, 2006) hypertrophy effect was observed after resistance exercise with slower movement tempo, but a lighter load compared to a faster tempo and heavier loads which partly can be related to the greater total time under tension (Burd et al., 2010, 2012; Schoenfeld et al., 2015; Wilk et al., 2020a).

Another factor which could affect the lack of a significant decrease in peak bar velocity in sets 2 and 3 for the S-E compared to the E-E condition may be related to the local blood flow restriction (Okamoto et al., 2004). The physiological effect of slower movement tempo during resistance exercise can be similar to what occurs during resistance exercise with external occlusion which causes blood flow restriction (Wilk et al., 2020a). The increase in performance observed for slow movement tempo can be related with a similar physiological effect induced by blood flow restriction, such as the release of nitric oxide, activation of the adenosine receptors, and opening of adenosine triphosphate (ATP)-dependent potassium (K+) channels which increase the energy stores after ischemia (Kimura et al., 2007; Pang et al., 1995; Paradis-Deschênes et al., 2015; Schroeder et al., 1996; Tanaka et al., 2016), thus increasing the effectiveness of resistance exercise (de Souza et al., 2019). Wilk et al. (2021b) showed that blood flow restriction used during rest periods significantly increased power output and bar velocity during the bench press exercise at 60%1RM (5 sets of 3 repetitions). The increase in bar velocity and power output performance was also observed when blood flow restriction was applied during exercise. Wilk et al. (2020c) showed that blood flow restriction used during exercise increased bar velocity and power output during the bench press exercise. Furthermore, previous studies have shown an increase in performance following blood flow restriction used during the warm-up (Guilherme

da Silva Telles et al., 2020; Marocolo et al., 2016a, 2016b). Therefore, local blood flow restriction induced by slower movement tempo may also positively affect bar velocity changes during subsequent sets of a resistance exercise.

Although the results of the present study show that different movement tempo distribution during a multi-set resistance exercise may be used to enhance performance, there are some study limitations that should be addressed. There was a lack of physiological evaluations, which could provide additional possible explanations for the obtained results. Furthermore, there are numerous different combinations of movement tempo distribution which can be employed through a set or between sets, therefore, the obtained results only apply to the movement tempo and exercise used in this study. Thus, further studies related to the distribution of movement tempo are necessary.

Practical implications

The present study showed that different distribution of movement tempo during a multi-set bench press exercise has a significant impact on peak bar velocity, but not on mean bar velocity. However, the decrease in peak bar velocity in the 3rd repetition under the S-E condition was observed only in the first set and such a negative impact was not observed in sets 2 and 3. The combination of slow and explosive movement tempo during a set can be useful, especially for complex resistance training aimed at developing strength, hypertrophy, and power output simultaneously (Krzysztofik et al., 2019; Wilk et al., 2020a). For power development, training with the intention of moving the bar explosively is optimal (Fielding et al., 2002; Haff and Stone, 2015; Fernandes et al., 2018), while intentional slowing down of movement tempo may increase muscle activity and metabolic response which could positively mediate intracellular anabolic signaling, which is thought to be one of the driving factors for increased muscular strength and hypertrophy (Kubo et al., 2002; Burd et al., 2012; Schoenfeld et al., 2015). Therefore, maintaining mean bar velocity in a multi-set exercise while increasing physiological responses during resistance exercise with slower first two repetitions can be a significant factor determining the level of post-exercise adaptive changes.

Conclusions

The results of the present study indicate that slower eccentric tempo used during initial repetitions affects peak bar velocity in the last, 3rd repetition of a bench press exercise. However, even if the use of slow movement tempo during the first two repetitions (S-E) causes a decrease in peak bar velocity in the 3rd repetition, this negative effect applies only to the first set of resistance exercise and not to the subsequent sets.

Furthermore, the different distribution of movement tempo does not change mean bar velocity between conditions. Therefore, the use of different movement tempo distribution can be useful, especially during complex resistance training. Slow repetitions can be effective in stimulating muscle strength and hypertrophy, while explosive movement tempo is optimal for power performance.

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