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The effect of a single cycle of ischemia on bar velocity during bench press exercise

Marta BICHOWSKA-PAWĘSKA
Gdansk University of Physical Education and Sport, Gdansk, Poland, marta.bichowska@awf.gda.pl

Dawid GAWEŁ
Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, d.gawel@awf.katowice.pl

Robert TRYBULSKI
Department of Medical Science; The Wojciech Korfanty School of Economics, Katowice, Poland, rtrybulski@o2.pl

Jakub JAROSZ
Institute of Sport Sciences; Jerzy Kukuczka Academy of Physical Education in Katowice, Poland, j.jarosz@awf.katowice.pl

Kinga ŁOSIŃSKA
Gdansk University of Physical Education and Sport, Gdansk, Poland, kinga.losinska@awf.gda.pl

See next page for additional authors

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Abstract

Introduction: The main goal of this study was to investigate the effects of a single cycle of ischemia applied before the bench press exercise on acute bar velocity changes. Materials and Methods: Twelve physically active males participated in the study. The experiment followed a rando-mized, cross-over design under two testing conditions. The experimental condition involved the application of a single cycle of ischemia (5 minutes; 80% arterial occlusion pressure [AOP]) before the first set of bench press exercise (2 sets at 60% 1RM). The control condition did not use ischemia. The peak and mean bar velocities were measured using a linear position transducer. Results: Two-way repeated measures ANOVA revealed no statistically significant differences in the peak or mean bar velocity between the ischemia and control conditions both during the first and the second set of the bench press exercise. Conclusions: The results of this study indicate that a single cycle of ischemia applied before the bench press exercise did not influence changes in peak or mean bar velocity.

Keywords

blood flow restriction, BFR, occlusion, reperfusion, resistance exercise, training, sports performance, explosive strength

Authors

Marta BICHOWSKA-PAWĘSKA, Dawid GAWEŁ, Robert TRYBULSKI, Jakub JAROSZ, Kinga ŁOSIŃSKA, Krzysztof FOSTIAK, and Joao Guilherme VIEIRA

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Article

The effect of a single cycle of ischemia on bar velocity during bench press exercise

Marta BICHOWSKA-PAWĘSKA[1], Dawid GAWEŁ[2], Robert TRYBULSKI[3], Jakub JAROSZ[4], Kinga ŁOSIŃSKA[5], Krzysztof FOSTIAK[6], João Guilherme VIEIRA[7]

[1] Gdansk University of Physical Education and Sport, Gdansk, Poland; ORCID 0000-0001-6327-9879
[2] Institute of Sport Sciences, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland; ORCID 0000-0001-5884-9478
[3] Department of Medical Science; The Wojciech Korfanty School of Economics, Katowice, Poland; ORCID 0000-0002-4276-4813
[4] Institute of Sport Sciences; Jerzy Kukuczka Academy of Physical Education in Katowice, Poland; ORCID 0000-0002-6506-8263
[5] Gdansk University of Physical Education and Sport, Gdansk, Poland; ORCID 0009-0009-0227-106X
[6] Gdansk University of Physical Education and Sport, Gdansk, Poland; ORCID 0000-0003-2455-2996
[7] Postgraduate Program in Physical Education, Strength Training Research Laboratory, Federal University of Juiz de Fora (UFJF), Juiz de Fora, Brazil; ORCID 0000-0002-3860-4630

* Correspondence: Dr Marta Bichowska-Pawęska; e-mail: marta.bichowska@awf.gda.pl

Abstract: Introduction: The main goal of this study was to investigate the effects of a single cycle of ischemia applied before the bench press exercise on acute bar velocity changes. Materials and Methods: Twelve physically active males participated in the study. The experiment followed a randomized, cross-over design under two testing conditions. The experimental condition involved the application of a single cycle of ischemia (5 minutes; 80% arterial occlusion pressure [AOP]) before the first set of bench press exercise (2 sets at 60% 1RM). The control condition did not use ischemia. The peak and mean bar velocities were measured using a linear position transducer. Results: Two-way repeated measures ANOVA revealed no statistically significant differences in the peak or mean bar velocity between the ischemia and control conditions both during the first and the second set of the bench press exercise. Conclusions: The results of this study indicate that a single cycle of ischemia applied before the bench press exercise did not influence changes in peak or mean bar velocity.

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1. Introduction

Ischemia, or blood flow restriction, is a non-invasive training method that involves the use of inflatable cuffs or tourniquets applied around the most proximal parts of the upper or lower limbs in order to temporarily restrict the blood flow, causing hypoxia within the muscle tissue [1, 2]. Exercise and health-related benefits of blood flow restriction have been well documented among various populations with different forms of physical activity [3–7]. Acute physical responses, as well as chronic adaptations following ischemia, are most often attributed to increased metabolic stress, muscle fiber recruitment, and cellular swelling. Furthermore, blood flow restriction has been shown to enhance intramuscular signaling for protein synthesis, and proliferation of myogenic stem cells [8]. In addition, the application of ischemia during physical activity causes the accumulation of certain by-products, such as lactate and hydrogen ions, which might cause an increase in afferent signals from intramuscular metaboreceptors, resulting in an increased growth hormone response [9, 10].

Various methods of applying ischemia have been established, such as ischemic preconditioning (ischemia used only before an exercise) [11], ischemic post-conditioning (ischemia applied after an exercise) [12], continuous ischemia (ischemia used during an exercise and during the rest interval) [13], intermittent ischemia (ischemia used only during an exercise) [7], and ischemic intra-conditioning (ischemia used only during the rest interval) [14, 15]. Among the aforementioned modes of blood flow restriction training, ischemic intra-conditioning constitutes an emergent, innovative, and relatively simple method. It involves the application of ischemia only during the rest intervals and therefore does not directly interfere with the training tasks. Moreover, it mitigates the perception of discomfort compared to other methods of applying ischemia [16, 17]. However, currently, only a few studies have examined the effects of ischemic intra-conditioning during resistance exercise on acute performance changes. In one study, Wilk et al. [18] showed a significant increase in bar velocity during the bench press exercise (5 minutes of ischemia; 80% arterial occlusion pressure [AOP], 60% 1 repetition maximum [RM]). However, such increases were recorded only in sets 3–5, suggesting that the use of ischemia during rest intervals allows maintaining high levels of power performance during increasing fatigue. Similarly, Trybulski et al. [19] reported a lower decline in power output during the Keiser squat exercise (4.5 minutes of ischemia; 60% AOP; 60% 1RM). Thus, it might be concluded that ischemia may counteract increasing fatigue in both upper and lower limbs during resistance exercise. Finally, Trybulski et al. [20] showed that ischemic intra-conditioning did not change the strength-endurance capabilities when bench press exercise was performed to failure (4.5 minutes of ischemia; 80% AOP; 70% 1RM). Although some studies indicate the beneficial effect of ischemic intra-conditioning, the vast majority of the available literature remains contradictory. Furthermore, it is still impossible to precisely determine various methodological factors such as appropriate cuff pressures, the amount and duration of ischemia cycles, or the duration of rest intervals [14, 19].

Notably, it has been shown in a recent study that even a single cycle of ischemia may be sufficient to achieve positive physiological changes [11]. Salagas et al. [11] showed that 5-minutes of ischemia with 100% AOP used before the bench press exercise increased bar velocity at 60% 1RM. Similarly, Jarosz et al. [14] also showed that a single cycle of ischemia (3 minutes of ischemia; 80% AOP) used before a low-load bench press exercise (20% 1RM) increased peak bar velocity. However, in this study, the subjects performed 8 sets of the bench press exercise with a 10% increase in subsequent sets (from 20% 1RM to 90% 1RM), and no such increases were recorded at the load of 60% 1RM, which is in contrast to previous studies [11, 18, 19].

The positive changes after a single cycle of ischemia were observed when high cuff pressures (80% and 100% AOP) were applied; however, to this day no other study has investigated the impact of a single cycle of ischemia used directly before the first set of exercises. Therefore, the aim of the study was to determine whether a single ischemia cycle (80% AOP) significantly affects changes in bar velocity and whether such an effect would be maintained in subsequent sets. The bench press exercise has been chosen as it was also utilized in previous research. It was hypothesized that one cycle of ischemia applied before the bench press exercise would increase bar velocity during both sets of the bench press exercise.

2. Materials and Methods

2.1. Study Design

The study was conducted according to a randomized crossover design, wherein each participant underwent two distinct testing protocols (1 ischemia condition and 1 control condition), arranged 7 days apart. The experiment was preceded by a 1RM strength test and a familiarization session one week before the main testing sessions. The experimental protocol involved the use of ischemia only before the first set of the bench press exercise, while the control condition did not use ischemia. During the ischemic condition, cuff pressure was set to ~80% AOP. During each experimental session, subjects performed 2 sets of 5 repetitions of the bench press exercise at a load of 60% 1RM with a 5-minute rest interval. Each repetition was performed with a maximal tempo in the eccentric and concentric phases of the movement [21, 22]. The peak and mean bar velocity were measured using a linear position transducer. All testing sessions were performed in the Strength and Power Laboratory at the Academy of Physical Education in Katowice, Poland. The experimental procedure did not change at any stage of the experiment.

2.2. Participants

Twelve physically active males (age: 23.2 ± 2.7 years, height: 177.5 ± 6.6 cm, weight: 83.1 ± 10.9 kg) volunteered for the study. The inclusion criteria were: a) free from neuromuscular and musculoskeletal disorders, b) at least 1 year of resistance training experience, c) free of cardiovascular disease, including arterial hypertension, atrial fibrillation, thrombosis, and myocardial insufficiency (self-declaration). Participants were advised to adhere to their regular dietary and sleep habits and to refrain from stimulants throughout the experiment. The participants were fully informed about the potential risks of the study and the possibility of withdrawing at any time before providing their written informed consent. The study was approved by the Bioethics Committee for Scientific Research at the Academy of Physical Education in Katowice, Poland (2/2019), in accordance with the ethical standards of the Declaration of Helsinki, 1983.

2.3. Procedures

2.3.1. 1RM Strength Test and Familiarization Session

One week before the main experiment, the participants performed a 1RM strength test and a familiarization session. After arrival, subjects cycled on a cycle ergometer for 5 minutes at an exercise intensity that induced a heart rate of ~130 bpm, followed by a general upper body warm-up as described elsewhere [23]. Then, participants performed 15, 10, 5, 3 bench press repetitions using 20, 40, 60, and 80% of their estimated 1RM, respectively. Then the load was increased by 2.5 to 10 kg for each subsequent attempt [24]. This process was repeated until failure (within a maximum of five attempts). The rest interval between successful trials was 5 minutes. After completing the 1RM test and recovering for 15-minutes, participants performed 3 sets of 3 repetitions of the bench press exercise with a load of 60% of their estimated 1RM with ischemia (50% AOP) used before the first set of the bench press exercise [18]. The familiarization session was performed to minimize possible learning effects during the main testing sessions. Hand placement on the barbell as well as movement tempo during the 1RM strength test and familiarization session were voluntary. Testing was performed using an Olympic barbell (2.8 cm diameter, 1.92 m length) (Eleiko International, Halmstad, Sweden).

2.3.2. Experimental Sessions

During the ischemic condition, a single cycle of ischemia was applied before the first set of exercises. However, for the control condition, ischemia was not applied. During both experimental conditions, subjects performed 2 sets of 5 repetitions of the bench press exercise at a load of 60% 1RM and a 5-minute rest interval between sets. In an ischemic condition, the cuff pressure was set to ~80% AOP. A linear position transducer (Tendo Power Analyzer, Tendo Sport Machines, Trencin, Slovakia) was utilized to measure peak and mean bar velocity [25, 26]. Peak bar velocity was obtained from the best repetition per-formed in each set. The mean bar velocity was determined as the average of five repetitions performed in each set.

2.3.3. Ischemic procedure

For the ischemic condition, pressure cuffs were applied bilaterally, as high as possible, near the axillary fossa. The SmartCuffs (Smart Tools Plus LLC, Strongsville, OH, United States), which have a width of 10 cm, were utilized for this experiment. Ischemia was applied for 5 minutes before the first set (including ~30 s to inflate and ~10 s to deflate the cuffs). The cuff pressure was set to ~80% AOP (119 ± 21 mmHg). To determine each participant's AOP, after the completion of the general warm-up and a 5-minute rest interval, the value of full arterial occlusion pressure (100% AOP) was determined (subjects remained in a seated position) using a handheld Edan SD3 Doppler equipped with an OLED screen and a 2 mHz probe (Edan Instruments Inc., Shenzhen, China). The probe was placed over the radial artery to assess the blood pressure required for the cessation of the auscultatory pulse, as described in previous studies [18, 20]. The measurement was conducted twice on each limb, and the obtained differences were within 20 mmHg, with the average value used to set the cuff pressure for the exercise protocol [18].

2.4. Statistical Analysis

All statistical analyses were performed using Statistica 9.1. Results are presented as means and standard deviations. The Shapiro-Wilk test was used to verify the Gaussian distribution, homogeneity, and sphericity of the sample data variances, respectively. Differences between the conditions were examined using a two-way repeated measures ANOVA [2 conditions (ischemia at 80% AOP vs. control) × 2 sets of bench press]. Effect sizes (ES) for main effects and interactions were determined by partial eta squared (η^2). Partial eta squared values were classified as small (0.01–0.059), moderate (0.06–0.137), and large (>0.137). Post hoc comparisons using Tukey's test were conducted to locate the differences between mean values when the main effect or interaction was found. For pairwise comparisons, ESs were determined by Cohen's *d* which was characterized as large ($d > 0.8$), moderate (d between 0.8 and 0.5), small (d between 0.49 and 0.20), and trivial ($d < 0.2$). Percentage changes with 95% confidence intervals (95CI) were also calculated. Statis-tical significance was set at $p < 0.05$.

3. Results

The two-way repeated measures ANOVA for peak bar velocity did not show statistically significant condition × set interaction (conditions × sets; $p = 0.53$; $\eta^2 = 0.06$; Table 1). There was no main effect of conditions ($p = 0.19$; $\eta^2 = 0.22$), either.

Table 1. Peak bar velocity during two sets of bench press exercise under two experimental conditions.

Peak Velocity	Control	80% AOP	*p* for interaction	*p* for main effect of condition
Set 1	1.04 ± 0.19	1.03 ± 0.13	0.53	0.19
Set 2	1.04 ± 0.15	1.00 ± 0.17		

All data are presented as mean with standard deviation. AOP = arterial occlusion pressure.

The two-way repeated measures ANOVA for mean bar velocity did not show statistically significant condition × set interaction (conditions × sets; $p = 0.86$; $\eta^2 = 0.004$; Table 2). There was no main effect of conditions ($p = 0.31$; $\eta^2 = 0.14$), either. The ES for the two experimental conditions for all measured variables is showed in Table 3.

Table 2. Mean bar velocity during two sets of the bench press exercise under two experimental conditions.

Mean Velocity	Control	80% AOP	*p* for interaction	*p* for main effect of condition
Set 1	0.76 ± 0.13	0.74 ± 0.10	0.86	0.31
Set 2	0.76 ± 0.13	0.73 ± 0.13		

All data are presented as mean with standard deviation. AOP = arterial occlusion pressure.

Table 3. Differences in effect size between two experimental conditions.

Mean Velocity		
Control vs. 80% AOP	Set 1	Set 2
	0.03	0.23
Peak Velocity		
Control vs. 80% AOP	Set 1	Set 2
	0.06	0.25

AOP = arterial occlusion pressure.

4. Discussion

The main finding of the present study is that a single cycle of ischemia applied before the bench press exercise did not increase peak or mean bar velocity at 60% 1RM. The lack of significant differences occurred both during the first and the second set of the exercises. Therefore, it might be concluded that a single cycle of ischemia applied before the first set of the bench press exercise influences acute power performance changes, which is contrary to our initial hypothesis.

The results of this experiment are partially in contradiction to previous studies related to this matter [11, 14]. However, the acute effect of ischemia on power performance can be related to various factors, including training variables as well as parameters of ischemia, and therefore should be further considered. Currently, only two studies have reported an increase in power performance following a single ischemia cycle [11, 14]. Salagas et al. [11] showed an increase in mean and peak bar velocity during the bench press exercise after one cycle of ischemia (5 minutes). This intervention caused an increase in bar velocity not only during the first set of bench press exercise but also in sets 2–3, but not during the fourth one. Although effective, such an application of ischemia might be inadequate to influence acute power performance changes for longer than three sets. Furthermore, it has also been found by Ghosh et al. [27] that only 4 minutes of ischemia is required to reach the threshold for the ischemic stimulus in humans. However, it is still unknown whether higher pressure or a longer duration of ischemia would result in superior acute responses. It is of particular note that in the study by Salagas et al. [11], higher cuff pressure (100% AOP) was used, compared to the presented study (80% AOP). The importance of high cuff pressure has been shown in blood flow restriction research regarding power output and strength performance [28, 29], although with the use of different modes of ischemia. It seems reasonable to consider the application of higher cuff pressure, even exceeding 100% AOP [11, 28, 29], especially given that in previous studies related to ischemic intra-conditioning, lower cuffs pressure (60–80% AOP)was most often used, and no increase in power performance following a single cycle of ischemia was reported [18, 19]. Thus, lower cuff pressure, although shown to be effective in counteracting increasing fatigue, might be insufficient to cause immediate increases in power performance. Moreover, the study by Salagas et al. utilized ischemic pre-conditioning, stating a significant distinction between study protocols. Subjects rested for 5 minutes subsequent to the ischemia application. This 5-minute period is referred to as reperfusion, and it involves restoration of the blood flow and simultaneous reoxygenation following a prior restriction of blood circulation [30]. It has been suggested as a critical factor in determining how effective ischemia is when it is applied during resting periods between exercise sets [19].

Furthermore, in the second study by Jarosz et al. [14], the authors showed a significant increase in the peak but not in the mean bar velocity following a single cycle of ischemia during a protocol consisting of 8 sets of the bench press exercise (10% increase in a subsequent set from 20 to 90% 1RM; 3 minutes of ischemia; 80% AOP). However, such in-creases did not occur in subsequent sets, except for the fourth one (50% 1RM). Therefore, a relationship between the % AOP and the external load used might exist. However, the ap-plied ascending external load as well as the shorter duration of ischemia may also have influenced the results.

It is still unknown which factors are primarily responsible for inducing acute responses following a single cycle of ischemia. Among many factors, the cuff pressure, the number of ischemia cycles, and the duration of ischemia seem to be of importance [14, 18, 19]. Considering that the current state of knowledge is limited to the results of only a few studies, two directions can be observed in both pre-conditioning ischemia and ischemic intra-conditioning. Firstly, the mechanisms responsible for the increase in performance may be similar to the effect of PAPE, which relates to an acute enhancement of muscle performance following a series of maximal or submaximal muscle actions [11, 31]. Secondly, the application of ischemia may counteract the increasing fatigue during subsequent sets of resistance exercises [18, 19]. Given a lack of significant increases in power performance after a single, but not consecutive cycles of ischemia at 80% AOP observed in previous studies [18, 20], it seems reasonable to assume that increasing the number of ischemia cycles before and between sets of resistance exercises with the same cuff pressure might lead to maintaining or improving power output despite accumulating fatigue. However, in order to achieve such an effect with a single dose of ischemia, pressure of at least 100% AOP seems to be necessary [11]. Furthermore, it should be noted that in the presented research, as well as in other aforementioned studies [18, 19], a decrease of velocity following a single cycle of ischemia was not observed. Moreover, different physiological responses, regrettably not assessed in this study, might have occurred, and thus possibly inducing chronic responses. For example, Torma et al. [32] reported that ischemia ap-plied during rest periods might influence mitochondrial biogenesis, time of muscle repair, or muscle hypertrophy [32].

5. Conclusions

The results of this study indicate that a single cycle of ischemia (80% AOP) applied before the bench press exercise did not influence changes in peak or mean bar velocity at 60% 1RM. The use of higher cuffs pressure (⩾100% AOP) might be necessary in order to achieve acute increases in power performance, and this issue should be further explored in future studies. Moreover, despite no acute impact on performance, such an application of ischemia might have induced different physiological responses and therefore positive chronic muscle adaptation, which was not evaluated in this study.

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