Original Article (short paper)

The effects of high-intensity warm-up sets on bench press strength

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Abstract - Aims: Movement specific warm-up is a widely accepted practice in the sports environment; however, little is known regarding the ideal intensity of its performance. To verify the effects of adding high-intensity sets to the warm-up on strength, muscular electrical activity, and body temperature in the bench press exercise. **Methods:** Twelve men (21±1.7 years, 23.9±3.5 kg.m^2) were evaluated by a maximal repetition test (1-RM), after which the volunteers performed three procedures: Low-intensity warm-up (LIW), low-intensity warm-up with high-intensity sets (WHI), and no warm-up (CON). Next, they performed maximal isometric voluntary contractions (MIVC) of the chest press to assess the electromyographic activity of the pectoralis major, peak rate of force, development (RFD$_{peak}$), and maximum strength (S$_{max}$). The skin temperature was evaluated before starting the test. **Results:** No between-condition differences ($p \leq 0.05$) were found for S$_{max}$ (CON = 320.3±83.8 N; LIW = 300.1±131.6 N, HIW = 327.0±113.9 N; p = 0.689), RFD$_{peak}$ (CON = 4399±1776 Ns^{-1}; LIW = 3476±1905 Ns^{-1}; HIW = 4715±2184 Ns^{-1}; p = 0.243), skin temperature (CON = 34.0 ±1.0 °C, LIW = 34.9±0.8 °C, HIW = 34.8±1.1 °C; p = 0.078) or myoelectric activity according to the root mean square index of sternocostal (p = 0.402) and clavicular (p = 0.535) heads, as well as the median frequency data of sternocostal (p = 0.169) and clavicular heads (p = 0.456). **Conclusion:** In conclusion, the proposed warm-up protocols were not able to modify strength, muscle electrical activity, or skin temperature in the bench press exercise.

Keywords: post-activation potentiation; rate of force development; electromyography; body temperature.

Introduction

Warming-up is a widely accepted practice in a sporting environment, with coaches and athletes believing it is essential to improve performance in subsequent tasks[1]. Conditioning activities can be a strategy warm-up, being them specific (exercises similar to the activity of interest), general (aerobic activities), or composed of stretching methods[2]. The improvement in performance caused by the conditioning activity has been associated with some mechanisms that include neural effects and increased body temperature, anaerobic metabolism, oxygen consumption kinetics, and post-activation potentiation (PAP)[1].

However, for this improvement to materialize in active warm-ups, the intensity seems to be an important factor to consider. According to the systematic review of Maccrary et al.[3], high-intensity conditioning activities for the upper body improved strength and power in 76% of investigated studies, whereas 63% of the low-intensity warm-up studies were not found improvement. Besides that, another meta-analysis[4] found that moderate-intensity (60–84% 1RM) exercise is better than very high-intensities (> 85% 1RM) for eliciting PAP in power. This meta-analysis also showed that training experience (with better responses in athletes), multiple sets, and moderate rest periods (7 to 10 minutes) improve the PAP effects in power.

Since warm-ups with higher intensities can have positive effects on strength performance[3] and in a way that can maintain the safety of your practice[5], a strategy used is progressive warm-ups, which adds sets of greater intensity. Among several possible strength tests, the isometric resistance test has a remarkable relationship with the performance of dynamic strength and is used to measure the maximum strength (S$_{max}$) and rate of force development (RFD)[6], both objects of evaluation of the present study and other studies[7,8] and directly related to weightlifting performance[9].

To date, the literature shows few results on the effects of a specific warm-up on the bench press strength. Wilcox et al.[10] compare two protocols of explosive-force movements and found an increase in dynamic strength, measured employing a 1-RM test, 30 seconds after both protocols. Farup & Sorensen[7] found not an improvement in S$_{max}$ and a decrease in RFD after a high load warm-up. Besides that, only Brandenburg[11] who compares three protocols (100, 75, and 50% of 5RM) in the bench press, and West et al.[12] that compare two protocols (87% and 30% of 1RM) in the bench press, study the effect of warm-up intensity.

Brandenburg[11] found no improvements in explosive performance, while West et al.[12] found improvement of peak power output in both protocols. Thus, there are still gaps, such as the number of series and the intensity of conditioning activities, when the focus is on the evaluation of S_{max} and RFD in the bench press strength.

Thus, due to the importance of muscular strength in competitive event performance and the scarcity of results about the effect of warm-ups on this capacity, the objective of the present study was to verify the effects of adding high-intensity sets to the warm-ups on the bench press strength.

Methods

Participants

Twelve male volunteers, recreational resistance exercise practitioners with a minimum of six months of regular experience, with practice in the bench press exercise in their respective training programs, were recruited in an intentional non-probabilistic method. All volunteers reported that they did not have any neuromuscular or cardiovascular disorders. Participants signed a consent term respecting all norms of the National Health Council (466/12). All procedures were approved by the Human Research Ethics Committee of the Federal University of Uberlândia (number 974.358 / 2015).

Experimental design

This is a study with a controlled and randomized crossover design. The subjects attended the laboratory for four distinct sessions, with a minimum interval of 48 hours between sessions. In the first session, the general characteristic data were recorded and a maximal repetition test (1-RM) was applied in the guided bench press following the recommendations and procedures of Brown, Weir[13]as well as recommendations for the practitioner are also provided. The content is divided into sections covering isometric, isotonic, field tests, and isokinetic modes of exercise. Inherent in these modes are both concentric and eccentric muscle actions as well as both open and closed kinetic chain activities. For Isometric testing, contractions should occur over a four to five seconds duration with a one second transition period at the start of the contraction. At least one minute of rest should be provided between contractions. For each muscle tested at each position, at least three contractions should be performed although more may be performed if deemed necessary by the tester. For isotonic testing, the 1-RM test should be performed. After the general warm-up, the subject should perform a specific warm-up set of 8 repetitions at approximately 50% of the estimated 1-RM followed by another set of 3 repetitions at 70% of the estimated 1- RM. Subsequent lifts are single repetitions of progressively heavier weights until failure. Repeat until the 1-RM is determined to the desired level of precision. The rest interval between sets should be not less than one and not more than five minutes. The optimal number of single repetitions ranges from three to five. Data and guidelines of the following field tests are also provided; vertical jump, bench press, Wingate anaerobic cycle test (WAT). Subsequent sessions were used to assess maximal isometric strength, rate of force development, skin temperature, and electromyographic activity in three differ-ent situations: control without warm-up (CON), a low-intensity warm-up (LIW), and a low-intensity warm-up with high-intensity sets (HIW) in a cross-shaped and counterbalanced way. The subjects were instructed not to practice strenuous exercises in the 24 hours preceding the experimental situations, as well as to appear hydrated, fed, and always at the same time of day as the first evaluation.

Warm-up protocols

All warm-up or control situations were preceded by ten minutes at rest (sitting). The LIW was performed in 15 repetition sets at 40% 1-RM[14]. For the HIW, two minutes after the same warm-up protocol, the participants performed three repetitions at 90% of 1-RM with one minute of the interval between repetitions. For CON, the subjects did not perform any warm-up procedure.

Evaluation of Maximum Isometric Voluntary Contraction

The evaluation was performed on a Smith Machine (Axcess Fitness Equipment, Valinhos, SP, Brazil), with a length, width, and height of 1.20, 2.02, and 2.35 meters, respectively. The procedures adopted and load cell positioning (model 5000 N, EMG System ™, São José dos Campos, SP, Brazil) were as described by Pinto da Silva et. al.[15], using chains and carabiners to fix the load cell, always with the intention of leaving the volunteer's arm at 90º for the elbow joint. Prior to evaluations, the load cell was calibrated following the manufacturer's recommendations. Participants were familiarized with the procedures and instructed to produce force as fast as possible and then, MIVC was performed after seven minutes of warm-up (high or low intensity) or control. Volunteers performed two MIVCs of five seconds with an interval of two minutes between them. It is important to note that all individuals were familiarized with the procedures on separate occasions.

Analysis of Maximum Strength and rate of force development

The raw signal from the force transducer was digitally filtered by a second-order Butterworth low-pass filter with a cut-off frequency of 25 Hz. In addition, the onset of muscle strength production was defined as the point at which the value of muscle strength exceeded 7.5 Newtons above the baseline[16]. The MIVC was determined as the highest value recorded within the one-second window. The peak RFD (RFD_{peak}) was determined as the steepest slope of the isometric strength-time curve (ΔStrength/

ΔTime), calculated within regular 20-millisecond windows for the first 200 milliseconds from the onset of muscle strength production[16]. The RFD was also obtained for time intervals, between 0-30, 0-50, 0-100, and 0-200 ms, and the impulse was determined as the area under the curve moment-time in time 0-200 ms. All procedures were performed using MatLab 2013a software (MathWorks, Massachusetts, USA).

Electromyographic activity

Electromyographic activity signal recording was performed through an electromyograph (MyosystemBr1 P80, DataHominis Tecnologia Ltda., Uberlândia, MG, Brazil), consisting of a signal conditioner designed according to the norms of the International Society of Electrophysiology and Kinesiology. The sampling frequency used was 2000 Hz per channel throughout the collection, with the electromyograph adjusted for approximately 25-50 times gain depending on the amplitude of volunteer signals.

The electromyographic signals were collected using simple differential surface electrodes (DataHominisTecnologia Ltda., Uberlândia, MG, Brazil) consisting of two rectangular parallel bars of silver, 10mm in length, 1mm wide, and a 10mm distance between bars, with a 20-fold gain preamp circuit and 92 dB common-mode rejection ratio. The signals were collected using the specific software for the electromyograph (MyosystemBr1, version 3.5.6).

After preparation of the volunteers, with shaving and skin cleaning with 70% alcohol, the electrodes were positioned so that the bars of the elements (sensors) were both perpendicular to the direction of the fibers of the pectoralis major (PM) in the sternocostal (EST) and clavicular (CL) heads of the right antimere, following the recommendations of Clemons and Aaron[17]. Identification of anatomic points and electrode placement were performed by the same researcher. In addition, local maps of the evaluated region were made, with acetate paper, to ensure relocation in the same place at all visits[18].

After electrode placement, individuals performed specific movements of the investigated task in order to verify the correct positioning and to examine the quality of the electromyographic signal[19]. In addition, a reference electrode (*Bio-logic Systems* - SP Médica, Científica e Comercial Ltda., São Paulo, SP, Brazil) consisting of a stainless-steel disc (30 mm diameter x 1.5 mm thick), was attached to the skin on the right iliac crest. The electromyographic activity was quantified in the MIVC evaluation and represented by values of Root Mean Square (RMS) and Median Frequency (MF), obtained with specific routines in MatLab 2013a software (MathWorks, Massachusetts, USA).

Skin temperature analysis

To record skin temperature, a thermographic camera was used (FLIR model T420) with a measuring range between -20 °C and 1200 °C, an accuracy of ±2% (2 °C), and sensitivity of 0.05, calibrated according to the manufacturer's recommendations. The distance between the volunteers and the camera was standardized at one meter and the degree of emissivity was set at 0.98[20]. Subsequently, the images were analyzed using FLIR Tools® software, a rectangle being delimited on the breastplate using the anatomical points of the nipple line and the superior border of the sternum, for which the average region temperature was obtained. Skin temperature was recorded at rest (after ten minutes) and before the MIVC.

Statistical analysis

Data are presented as mean and standard deviation. To verify the normality of data, a Shapiro-Wilk test was used. Additionally, the Mauchly test was used to verify sphericity. If this assumption was not assumed, the Greenhouse-Geisser adjustment was applied. The one-factor (warm-up conditions, with 3 levels) analysis of variance for repeated measurements was applied to compare the total amount of force, RFD, RMS, MF, and skin temperature in the pre-MIVC situation. Effect sizes (ES) are reported as partial eta-squared and considered as small (0.01), moderate (0.1), and large (0.25) effects[21]. The level of significance was set at 5%.

Results

The sample consisted of 12 men aged 21±2 years, body mass of 75.8±12.3 kg, height of 176.8±8.7 cm, and percentage of body fat of 17.0±7.4%. When comparing each experimental condition, the S_{max} did not present a significant difference (F = 0.28; p = 0.689; ES = 0,025; power: 0.08). These values are shown in *figure 1*.

In turn, the peak value of RFD was not different (F = 1.53; p = 0.243; ES = 0.122; power = 0.25) between experimental conditions, as well as the RFD in all intervals: 0-30 ms (F = 1.97; p = 0.166; ES: 0.152; power = 0.35), 0-50 ms (F = 1.84; p = 0.186; ES = 0.143; power = 0.33), 0-100 ms (F = 1.21; p = 0.313; ES = 0.099; power = 0.22), 0-200 ms (F = 1.26; p = 0.299; ES = 0.103; power = 0.22) and the area under the curve (F = 1.75; p = 0.202; ES = 0.138; power = 0.30). Mean RFD values by intervals and peak and respective area under the curve are shown in *figure 2*.

RMS values were not different between experimental situations in either the sternocostal (F = 0.86; p = 0.402; ES = 0.073; power = 0.15) or clavicular heads (F = 0.60; p = 0.535; ES = 0.052; power = 0.13). Similarly, MF data from the sternocostal (F = 2.01; p = 0.169; ES = 0.154; power = 0.33) and clavicular heads (F = 0.67; p = 0.456; ES = 0.057; power = 0.12) demonstrated no significant statistical effects. These values are shown in *table 1*.

Skin temperature did not present significant statistical differences (F = 3.04; p = 0.078; ES = 0.138; power = 0.30) when comparing experimental situations. Informative data regarding temperature are shown in *figure 3*.

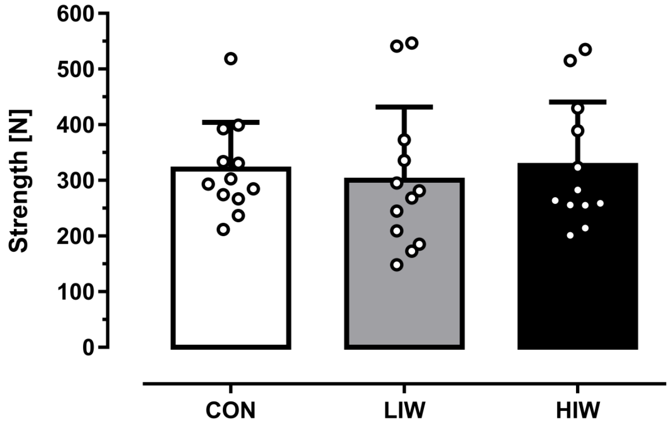

Figure 1 - Maximum isometric strength in different warm-up intensities on the bench press exercise. CON = control; LIW = low intensity warm-up; HIW = high intensity warm-up.

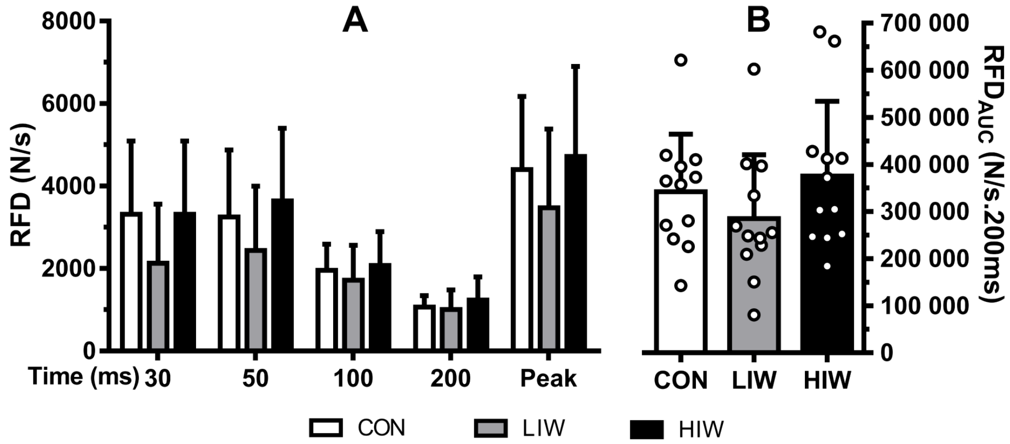

Figure 2 - Rate of the force development (Panel A) and its respective area under the curve (Panel B) in different warm-up intensities on the bench press exercise. CON = control; LIW = low intensity warm-up; HIW = high intensity warm-up; RFD = Rate of force development. RFD (Δmethod / Δtime) was calculated in time intervals of 0-30, 0-50, 0-100 and 0-200 ms (Δtime). Peak values were calculated within the range 0-200 ms.

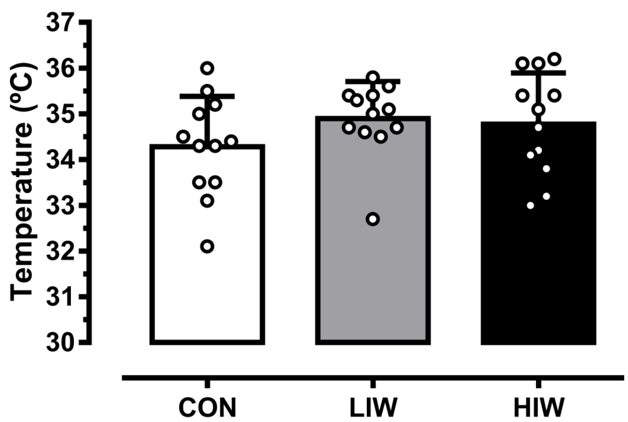

Figure 3 - Temperature before maximal isometric voluntary contraction in different warm-up intensities on the bench press exercise. CON = control; LIW = low intensity warm-up; HIW = high intensity warm-up.

Table 1 - Electromyographic activity of pectoralis major heads in different warm-up intensities on the bench press exercise.

	Pectoralis Major Head	CON (Mean±SD)	LIW (Mean±SD)	HIW (Mean±SD)
RMS	Sternocostal	283.8 ± 134.1	239.8 ± 108.0	276.5 ± 129.9
	Clavicular	199.0 ± 105.6	206.1 ± 92.26	183.9 ± 78.0
MF	Sternocostal	58.4 ± 10.2	65.8 ± 13.9	65.9 ± 16.5
	Clavicular	66.9 ± 18.1	68.2 ± 21.2	71.2 ± 21.4

CON = control; LIW = Low-intensity warm-up; HIW = High-intensity warm-up; SD = Standard deviation; RMS = Root mean square; MF: Median Frequency.

Discussion

The present study investigated the effect of adding high-intensity sets on specific warm-up on the bench press strength, and the results showed that the LIW or HIW did not change S_{max} or RFD in recreational resistance exercise practitioners. In addition, neuromuscular variables and body temperature were not different between the proposed experimental conditions.

About the effect of warm-up on the bench press, to our knowledge, only Farup & Sorensen[7] investigated the effect of a specific warm-up on S_{max} and RFD. This study did not demonstrate differences in S_{max} and indicated a reduction in RFD after the warm-up (5 sets of 1-RM). The authors justified their results based on the PAP theory, in which mechanisms of fatigue and muscular potentiation coexist within the skeletal muscle and that the relationship between these mechanisms determines whether there will be performance improvement or not[1]. The results of the present study corroborate the findings of Farup & Sorensen[7] on S_{max}, but not the RFD results. These differences may be related to the fact that their study did not present a control situation, as the decrease in RFD could be related to the accomplishment of several tests and not the warm-up.

Performance improvements after conditioning activities are usually associated with increased body temperature and/or PAP[7,22]. PAP is a phenomenon in which muscular performance increases when preceded by maximum or near-maximal exercises. This increase may be due to the phosphorylation of myosin regulatory light chains which increase the sensitivity of myofilaments to calcium[1]. The success of warming-up in producing a PAP response depends on the fatigue-potentiation balance and this is affected by the training experience, transition duration from warm-up, warm-up intensity, and percentage of myosin type 2 heavy chain isoform[1,23].

Thus, to better understand the mechanisms involved in the warm-up-performance relationship we evaluated the electrical activity of the pectoralis major and the skin temperature in this region. The results suggest that RMS, MF, and skin temperature were not significantly different between the proposed conditions. Some studies, such as Barnes et al.[24]; Esformes et al.[25]; Altamirano et al.[8]; and Stewart et al.[22] also investigated the muscular electrical activity, being that only Esformes et al.[25] study evaluated the pectoral electrical activity while the other studies assessed lower limbs muscles. Of these studies, only Stewart et al.[22] found a significant change in the electrical signal and justified this finding by an increase of more than 3°C in body temperature. In addition to this study, only Barnes et al.[24] and the present study also evaluated skin temperature, and both found no increases higher than 3°C after warming-up. Thus, the inability of the adopted warm-ups in our study to increase skin temperature, may in part explain the lack of improvement in performance parameters and neuromuscular responses.

Therefore, we have broadened the current understanding of warm-up effects on upper limb strength, since a recent systematic review[3] only found one study that evaluated the effect of different warm-up intensities on performance[11]. Thus, the present study is the first to show that in recreational resistance exercise practitioners, besides the warm-up protocols did not change the S_{max} and RFD, the intensities and volumes adopted for warming-up appear not to influence the strength performance, the skin temperature, or the muscle electrical activity. To summarize warm-up and warm-up with high-intensity sets (3 x 90% of 1RM) do not significantly affect the strength, the muscular electrical activity, or the skin temperature in the bench press exercise in healthy men.

Practical Application

Considering this in a practical environment, specific dynamic warm-ups, with or without high-intensity sets, are not required to improve the strength in the bench press exercise. It is important to clarify that these results cannot be extrapolated to other exercises and populations and new studies are necessary to fill these gaps.

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