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# The impact of general and/or specific warm-up on power and velocity during squat and bench-press training

# El impacto del calentamiento general y/o específico en la potencia y velocidad durante el entrenamiento de sentadilla y press de banca

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**Abstract.** The study aimed to compare the effects of two warm-up strategies on mechanical force production during bench press and squat resistance training sessions. Twenty-six trained male subjects (24.37±5.83years, 75.48±12.12kg, 1.74±0.07m) performed a squat or bench press resistance training session after a specific warm-up (SWU) or general warm-up followed by a specific warm-up (GSWU). The SWU included 2x6 repetitions at 32% and 64% of the maximal load (1RM), respectively. The GSWU included 10 minutes of treadmill running (70% of heart rate reserve) followed by SWU. The resistance training session consisted of 3x6 with a load of 80% 1RM. Mechanical (mean propulsive velocity, mean propulsive power and velocity loss), physiological [heart rate (HR), blood lactate concentration], and psychophysiological variables (rating of perceived exertion) were evaluated. In the bench press and squat resistance training sessions, no differences were found in the mechanical and psychophysiological variables. When performing the bench press, the GSWU caused an increased HR response after warm-up (100.00±16.93bpm *vs.* 110.57±9.69bpm, p=0.03; ES=0.65, moderate effect). GSWU or SWU can both be used as preparatory activities for bench press and squat resistance training performance without related restrictions. These findings may be helpful for professionals to provide appropriate warm-up strategies to maximize resistance training.
**Keywords**: Pre-exercise, Strength, T-Force, Velocity, Physiology, Resistance Training

**Resumen.** El objetivo del presente estudio fue comparar los efectos de dos estrategias de calentamiento sobre la producción de fuerza mecánica durante las sesiones de entrenamiento de resistencia en press de banca y sentadilla. Veintiséis sujetos masculinos entrenados (24.37±5.83 años, 75.48±12.12 kg, 1.74±0.07 m) realizaron una sesión de entrenamiento de resistencia en sentadilla o press de banca después de un calentamiento específico (SWU) o un calentamiento general seguido de un calentamiento específico (GSWU). El SWU incluyó 2x6 repeticiones al 32% y 64% de la carga máxima (1RM), respectivamente. El GSWU incluyó 10 minutos de carrera en cinta (70% de la reserva de frecuencia cardíaca) seguido de SWU. La sesión de entrenamiento de fuerza consistió en 3x6 con carga del 80% 1RM. Se evaluaron variables mecánicas (velocidad de propulsión media, potencia de propulsión media y pérdida de velocidad), fisiológicas [frecuencia cardíaca (FC), concentración de lactato en sangre] y psicofisiológicas (calificación del esfuerzo percibido). En las sesiones de entrenamiento de fuerza en press de banca y sentadilla no se encontraron diferencias en las variables mecánicas y variables psicofisiológicas. En las variables fisiológicas, el GSWU aumentó la respuesta de FC durante la sesión de entrenamiento de fuerza en press de banca (100.00±16.93 bpm *vs.* 110.57±9.69 bpm, p=0.03; ES=0.65, efecto moderado). Tanto GSWU como SWU se pueden utilizar como actividades preparatorias para el entrenamiento de resistencia en press de banca y sentadilla sin restricciones relacionadas. Estos hallazgos pueden ser útiles para que los profesionales proporcionen estrategias de calentamiento adecuadas para maximizar el entrenamiento de resistencia.
**Palabras Clave:** Pre-ejercicio, Fuerza, T-Force, Velocidad, Fisiología, Entrenamiento de resistencia

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## Introduction

Warm-up has been considered a fundamental practice to optimize performance and reduce the risk of injury (Bishop, 2003; Sánchez-Medina et al., 2017). Warm-up routines provide a reduction in discomfort at the start of an exercise program and a more motivating and proficient movement (Bishop, 2003; Nicoli et al., 2007). Although sports professionals and researchers are aware of the importance of warm-up and the literature has shown positive effects of warm-up strategies in different sports and activities (Gil et al., 2019; Ribeiro et al., 2020), the effects of warm-up on resistance training performance are still unclear (McGowan et al., 2015). Only a few studies have attempted to understand the effects of different warm-ups on strength performance (Ribeiro et al., 2020; Wilcox et al., 2006). Considering the importance of resistance training for completing physical tasks and optimizing performance, deeper knowledge about the effects of warm-ups seems to be useful to assist in maximizing performance (Ribeiro et al., 2021).

The usual practices during warm-up include a general component (i.e., a brief period of submaximal aerobic activity, such as running at low intensity) followed by a specific warm-up (i.e., a short-term higher intensity stimulation of the main muscles that will be recruited) (Gil et al., 2019). The importance of these two components of warm-up constitutes a general belief of coaches and athletes (Gil et al., 2019; Ribeiro et al., 2022). A general warm-up before a specific warm-up could induce significant neuromuscular adjustments that increase muscle force production capacity during dynamic tasks (Abad et al., 2011). Indeed, performing a general warm-up followed by explosive force upper-body movements (i.e., 2 plyometric push-ups or 2 medicine-ball chest passes) before the bench press exercise resulted in optimized values of the one repetition maximum (1RM) load (Wilcox et al., 2006). Nevertheless, recent research has mainly focused on the study of the specific part of the warm-up (e.g., Lopez-Álvarez & Sánchez-Sixto, 2021; Mancilla et al., 2023;). Specifically, considering resistance training, it was found that performing a specific warm-up only (i.e., included six repetitions with 40% of training load followed by six repetitions with 80% of training load in the bench press and squat exercises, with a one-minute interval before the resistance training) seems to enable higher movement velocity during the first training repetitions and greater peak velocities in less time in the bench press and squat training (Ribeiro et al., 2021). Comparing the impact of three distinct specific warm-ups (i.e., 2x6 repetitions with 40% and 80% of the training load *vs.* 6 x 80% of training load; *vs.* 6 x 40% training load), different responses were found depending on the type of resistance exercise used (Ribeiro et al., 2020). For example, the most favorable outcomes were observed after the warm-up with higher load in the squat and after progressive intensity in the bench press (Ribeiro et al., 2020). While there is scientific agreement on the positive influence of using warm-up before resistance exercises (Junior et al., 2014; Ribeiro et al., 2021; Wilcox et al., 2006), there are still some unclear conclusions about the most effective design of warm-up.

To the best of our knowledge, only a few studies tried to understand the effect of warm-up in resistance training sessions and most of them focused on the conventional 1RM load assessment (Junior et al., 2014; Ribeiro et al., 2020). However, it is known that 1RM load assessment can present several issues in the typical warm-up experimental research design. For example, a progressive increase of external loads is needed to evaluate the 1RM load and this compromises the experimental design by reducing the effectiveness of prior warm-up and/or increasing fatigue (Neiva & Marinho, 2023). However, research has been using mechanical variables (e.g., movement velocity, displacement) to monitor resistance exercise performance with accuracy (e.g., González-Badillo et al., 2010; Sánchez-Medina et al., 2017). The evaluation of the resistance exercise performance using these measures would allow a reliable analysis of the effect of previous warm-up procedures during an entire resistance training session. Furthermore, by using this linear position technology, it is possible to evaluate the response in each repetition of a submaximal resistance training set (González-Badillo et al., 2011; González-Badillo et al., 2017). Given that warm-ups can influence force production, it is important to analyze the effects of different warm-up routines to improve resistance training effectiveness. Therefore, the present study aimed to compare the effects of two warm-up routines (i.e., specific warm-up only, SWU *vs.* general followed by specific warm-up, GSWU) on the mechanical variables during different resistance training sessions using the bench press and squat exercises. It was hypothesized that a general warm-up followed by a specific warm-up would positively influence the mechanical responses, resulting from a greater ability to produce force in the resistance training session of the bench press and the squat exercises.

## Materials and methods

### *Participants*

Twenty-six physically active male subjects aged between 19 and 43 years volunteered to participate in the current study. Among these, fourteen men (mean ± SD: 26.21 ± 6.93 years of age, 75.28 ± 6.29 kg of body mass, 1.77 ± 0.07 m of height, and 1RM load of 76.07 ± 12.27 kg) were assessed using the bench press exercise, and twelve men (mean ± SD: 21.80 ± 2.20 years of age, 70.40 ± 15.75 kg of body mass, 1.71 ± 0.07 m of height, 1RM load of 81.17 ± 15.54 kg) were evaluated using the squat exercise. The division into groups was made according to the preference previously reported by the participants. Each participant was asked to report any previous illness, injury, or other physical problem that could impair their performance. All participants were verbally informed about the study procedures and read and signed a consent form. As inclusion criteria, participants should be male, over 18 years of age, have no limitations in the practice of physical activity, and have at least 6 months of experience in resistance training. Subjects who met the criteria and who voluntarily agreed to participate were included in the study. All procedures were in accordance with the Helsinki Declaration and approved by the local ethics board (Code n. º CE-UBI-Pj-2021-018:ID720).

### *Procedures*

A crossover research design was used to determine the effects of warm-up on mechanical responses, mean propulsive velocity (MPV), mean propulsive power (MPP), bar displacement, physiological (heart rate: HR; and blood lactate concentration), and psychophysiological variables (rating of perceived exertion, RPE). The first session was used for anthropometric assessment (height and body mass) and familiarization with the procedures, one week before the application of the experimental protocols. Height and body mass were measured (Seca Instruments, Ltd, Hamburg, Germany). Then, each participant carried out some practice sets with progressive intensity loads in the bench press and squat exercises. An experienced personal trainer, with more than 5 years of teaching, demonstrated the correct techniques and explained the protocols. The second session was used to evaluate the individual load-velocity relationships and to establish the maximal dynamic load (1RM) of each participant in the bench press and squat exercises. The third and fourth sessions were used to evaluate the bench press or squat training after SWU or GSWU. Each warm-up was performed randomly before performing the bench press or squat training, ensuring more than 48 hours between conditions. During the experimental period, the participants were asked to keep their usual food intake, refrain from caffeine and alcohol ingestion, and any strenuous exercise.

The exercises were performed using a Smith machine (Multipower Fitness Line, Perola, Murcia, Spain). A linear transducer sampling at 1000Hz (T-Force Dynamic Measurement System, Ergotech, Murcia, Spain) connected to a 16-bit analog to digital converter (Biopac MP100 Systems, Santa Barbara, CA, USA) was used to collect the bar displacement and velocity and automatically calculate the kinematic variables for every repetition (González-Badillo et al., 2011; González-Badillo et al., 2017).

*1RM assessment*

In the bench press exercise, each participant lay in the supine position on a flat bench with feet flat on the floor and hands placed slightly wider than shoulder-width on the barbell. Participants were instructed to lower the barbell to the chest, just above the nipples, in a controlled manner and, after approximately one second of pause, start the concentric phase of the movement as fast as possible, as described elsewhere (Pallarés et al., 2014). Participants were not allowed to bounce the barbell off their chests or to raise their shoulders or trunks off the bench (Sánchez-Medina & González-Badillo, 2011; González-Badillo et al., 2017).

In the squat exercise, each participant started from an upright position with knees and hips fully extended, hands placed slightly wider than shoulder-width on the barbell, and the barbell resting on the back at the level of the acromion. Then, they began to descend in a continuous motion the tops of the thighs got below the horizontal plane (eccentric phase), then immediately reversed motion, and ascended back to the upright position at maximum intended velocity (concentric phase) (González-Badillo et al., 2015; Sánchez-Medina & González-Badillo, 2011). Trained professionals (i.e., two strength coaches) were on both sides of the barbell to ensure safety.

In both resistance exercises (i.e., bench press and squat), the evaluator and strength coaches controlled the movement to guarantee that all repetitions were performed in the required technique with a similar range of movement. The initial load was fixed at 17 and 20 kg for all participants in the bench press and squat exercises, respectively, and was gradually increased by 10 kg increments. Each participant performed 3 repetitions with each load and the best repetition at each load, according to the criteria of fastest MPV, was considered (González-Badillo et al., 2015). The test finished for each participant when they reached concentric MPV of 0.4 $m.s^{-1}$ in the bench press and 0.6 $m.s^{-1}$ in the squat exercise, corresponding to 85% 1RM in both (Sánchez-Medina et al., 2017, Sánchez-Medina & González-Badillo, 2011). Inter-set recoveries ranged from three minutes (light loads) to five minutes (heavy loads). The 1RM was determined from the last MPV obtained during the progressive loading test as follows: (100 x load) / ($8.4326 \times MPV^2 – 73.501 \times MPV + 112.33$) for the bench press exercise (González-Badillo & Sánchez-Medina, 2010), and (100 x load) / ($-5.961 \times MPV^2 – 50.71 \times MPV + 117$) for the squat exercise (Sánchez-Medina et al., 2017).

### Resistance Training Session

The participants were randomly allocated into each warm-up condition: SWU or GSWU. The SWU involved two sets of six repetitions, with the $1^{st}$ set at 32% of the 1RM load and the $2^{nd}$ set at 64% of the 1RM load. These loads used in the specific warm-up corresponded to 40% and 80% of the load to be used in the resistance training session (Ribeiro et al., 2021). A one-minute rest interval was observed between sets. In the GSWU, the general part of the warm-up comprised 10 minutes of cardiovascular exercise (i.e., running on the treadmill), starting slowly (i.e., 50-55% HR reserve) until reaching a maximum of 70% HR reserve (Wilson et al., 2013) in the last two minutes. After resting for one minute, the SWU was performed. After the warm-up (GSWU or SWU), each participant performed the resistance training session. The resistance training session consisted of three sets of six repetitions with a load of 80% 1RM, with three minutes of rest between sets. The intensity of 80% 1RM is commonly used in traditional resistance training, and it is included in the propitious range of relative intensities (30-80% 1RM) that have been reported to improve long-term muscular performance (Pallarés et al., 2014). All the subjects were asked to self-report their fatigue level at the start of each training session and if there was fatigue, they would be dismissed and assessed the following day. Participants were asked to perform the concentric phase always at the maximum intended velocity.

All velocity measures corresponded to the propulsive phase of each repetition (González-Badillo & Sánchez-Medina, 2010; González-Badillo, Marques & Sánchez-Medina, 2011). For the analysis, it was considered the MPV (i.e., mean propulsive velocity value from the start of the concentric phase until the acceleration of the bar is lower than gravity) over each set, and the minimum MPV value (MPVmin) and the maximum MPV values (MPVmax) of the training session, the relative magnitude of MPV loss (VL) within the set and the training (calculated as the percent loss in MPV from the fastest to the slowest repetition) (Sánchez-Medina & González-Badillo, 2011), the peak velocity (PV: maximal instantaneous velocity value reached during the concentric phase at a specified load) (García-Pallarés et al., 2018) and the time to achieve PV (Time to PV) in each repetition. The exercise bar displacement (Displacement) was also measured. The displacement was measured by the distance that the barbell performed during the concentric phase of the resistance exercise in each repetition (Hornsby et al., 2018). In addition, considering the propulsive velocity and load, other mechanical variables were analyzed from the software output, such as the MPP value (MPP) in each set and the minimum MPP (MPPmin) and the maximum MPP (MPPmax) values of the training session.

### Physiological and psychophysiological variables

In all assessment sessions, participants were instructed to remain seated for five minutes without any effort. HR values were monitored with a polar watch (Polar, A300, Finland). HR values were recorded after five minutes of rest (resting HR), immediately after warm-up, and after completing the resistance training session. To determine blood lactate concentration, a portable lactate analyzer device (Lactate Pro 2, Japan) was used, with results obtained within ten seconds. The blood lactate values were obtained after five minutes of rest and immediately after the resistance training session. The 6-20 scale of Borg (Borg, 1998) was used after the warm-up condition and immediately after the resistance training session to obtain the individual perceived exertion.

### *Statistical Analysis*

For data analysis, Microsoft Excel 2007 was first used to extract data from the T-Force System. Afterward, the Statistical Package for Social Sciences (IBM SPSS® statistics for Windows, Version 27.0, IBM Corp., Armonk, NY, USA) was used for statistical analysis. To verify the normality of the data, the Shapiro-Wilk test ($n < 30$) was performed. After the normal distribution of the data was verified, the parametric tests were adopted. To compare the warm-up conditions (SWU *vs.* GSWU), the Student's paired t-test was used. The effect size (ES) was calculated to determine the magnitude of the differences between conditions. For this, Cohen's dz (ES) for within-subject comparisons was calculated using Laken's Excel spreadsheet (Lakens, 2013) and considered trivial (0 – 0.19), small (0.20 – 0.59), moderate (0.60 – 1.19), large (1.20 – 1.99), very large (2.00 – 3.99), and extremely large (4.00 and higher) (Hopkins et al., 2009). The level of statistical significance was set at $p \leq 0.05$.

## Results

The comparison of the effect of two warm-up strategies (SWU *vs.* GSWU) on mechanical force production, the mean values, standard deviations, differences, and effect sizes for mean propulsive velocity, velocity loss, peak velocity, time to peak velocity, displacement, and mean propulsive power in the first, second and third sets of the bench press exercise are presented in Table 1. No differences were found between the warm-up conditions in all variables assessed in the bench press resistance training session. Most of the effect sizes were found to be trivial, with some exceptions. For example, a greater effect size was found in the MPV during the first set (small), decreasing for the second and third sets (trivial). These results are supported by Figure 1 which shows an unclear tendency for comparisons between mean values throughout each repetition. For example, considering the mean, GSWU presented higher MPV values in four repetitions (out of six) during the first set, but only one in the second set and two in the third set.

Table 1.
Mean values ± standard deviation of mechanical responses in bench press exercise. Differences and confidence intervals (95% CI), p-values and effect sizes (ES) are also reported

| | SWU | GSWU | SWU vs. GSWU | | |
|---|---|---|---|---|---|
| | | | Mean ± CI (95%) | p | ES |
| MPV [set 1] ($m.s^{-1}$) | 0.52 ± 0.14 | 0.54 ± 0.15 | 0.01 ± 0.04 | 0.14 | 0.43 |
| MPV [set 2] ($m.s^{-1}$) | 0.52 ± 0.16 | 0.51 ± 0.17 | 0.00 ± 0.05 | 0.91 | 0.17 |
| MPV [set 3] ($m.s^{-1}$) | 0.50 ± 0.17 | 0.50 ± 0.18 | 0.00 ± 0.05 | 0.88 | 0.01 |
| MPVmin total ($m.s^{-1}$) | 0.35 ± 0.16 | 0.34 ± 0.18 | -0.01 ± 0.14 | 0.83 | 0.06 |
| MPVmax total ($m.s^{-1}$) | 0.53 ± 0.15 | 0.55 ± 0.15 | 0.02 ± 0.14 | 0.61 | 0.13 |
| VL [set 1] (%) | 0.09 ± 0.08 | 0.10 ± 0.05 | -0.01 ± 0.06 | 0.38 | 0.15 |
| VL [set 2] (%) | 0.09 ± 0.07 | 0.11 ± 0.05 | -0.01 ± 0.07 | 0.33 | 0.28 |
| VL [set 3] (%) | 0.11± 0.06 | 0.09 ± 0.05 | 0.01 ± 0.07 | 0.46 | 0.31 |
| VL [total] (%) | 24.76 ± 11.30 | 23.35 ± 10.56 | 1.40 ± 7.84 | 0.54 | 0.17 |
| PV [set 1] ($m.s^{-1}$) | 0.81± 0.18 | 0.82 ± 0.18 | 0.01 ± 0.09 | 0.47 | 0.10 |
| PV [set 2] ($m.s^{-1}$) | 0.80 ± 0.19 | 0.79 ± 0.21 | 0.01 ± 0.12 | 0.82 | 0.08 |
| PV [set 3] ($m.s^{-1}$) | 0.76 ± 0.22 | 0.75 ± 0.24 | 0.01 ± 0.09 | 0.64 | 0.10 |
| PV [total] ($m.s^{-1}$) | 0.83 ± 0.17 | 0.85 ± 0.19 | 0.01 ± 0.09 | 0.61 | 0.21 |
| Time to PV [set 1] (s) | 605.42 ± 168.89 | 637.42 ± 130.42 | 32.00 ± 145.61 | 0.42 | 0.21 |
| Time to PV [set 2] (s) | 568.57 ± 177.03 | 633.28 ± 221.34 | 64.71 ± 248.31 | 0.34 | 0.26 |
| Time to PV [set 3] (s) | 570.21 ± 250.23 | 626.78 ± 298.41 | 56.57 ± 340.40 | 0.54 | 0.16 |
| Displacement [set 1] (m) | 0.42 ± 0.06 | 0.43 ± 0.06 | 0.01 ± 0.02 | 0.29 | 0.37 |
| Displacement [set 2] (m) | 0.42 ± 0.07 | 0.42 ± 0.07 | 0.00 ± 0.04 | 0.67 | 0.01 |
| Displacement [set 3] (m) | 0.42 ± 0.07 | 0.43 ± 0.07 | 0.01 ± 0.03 | 0.26 | 0.33 |
| MPP [set 1] (W) | 262.86 ± 63.72 | 269.53 ± 62.98 | 6.66 ± 18.79 | 0.20 | 0.35 |
| MPP [set 2] (W) | 265.13 ± 71.49 | 254.67 ± 64.72 | -10.46 ± 48.73 | 0.43 | 0.21 |
| MPP [set 3] (W) | 266.18 ± 65.07 | 270.25 ± 57.58 | 4.06± 21.05 | 0.51 | 0.19 |
| MPPmin total (W) | 170.96 ± 76.14 | 171.57 ± 71.13 | 0.60 ± 34.31 | 0.94 | 0.01 |
| MPPmax total (W) | 280.65 ± 84.80 | 281.41 ± 77.21 | 0.76 ± 35.97 | 0.93 | 0.02 |

SWU: Specific warm-up; GSWU: general plus specific warm-up; MPV: mean propulsive velocity; MPVmin total: mean propulsive velocity minimum total; MPVmax total: mean propulsive velocity maximum total; VL: velocity loss; VL [total]: velocity loss total; PV: peak velocity; Time to PV: time to peak velocity; Displacement: exercise displacement; MPP: mean propulsive power; MPPmin total: mean propulsive power minimum total; MPPmax total: mean propulsive power maximum total.

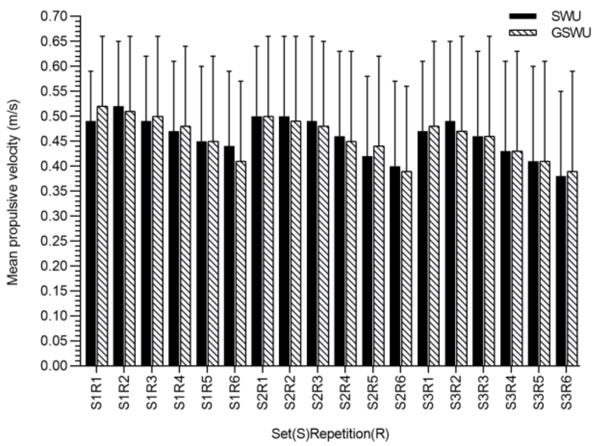


Figure 1. Mean propulsive velocity values in each repetition performed during bench press resistance training session. Values obtained in the six repetitions (R) during the first, second and third sets (S) of specific warm-up (SWU) and general plus specific warm-up (GSWU)

The mean values, standard deviations, differences, and effect sizes for the mean propulsive velocity, velocity loss, peak velocity, time to peak velocity, displacement, and mean propulsive power in the first, second, and third sets in the squat exercise are presented in Table 2. In the squat resistance training session, no differences were found between conditions in all variables. Small or trivial effect sizes were found in all comparisons. Like the bench press, the greater effect size between SWU and GSWU in the squat training session was found in MPV during the first set (small magnitude), decreasing for the second and the third sets (trivial). More detailed information about MPV for each repetition in SWU or GSWU can be found in Figure 2. It can be verified that GSWU presented higher MPV values in two repetitions (out of six) during the first set, five repetitions in the second set, and only two repetitions in the third set, highlighting the unclear differences between warm-ups.

There were no differences between the SWU and the GSWU in displacement, either in the bench press (Table 1) or the squat (Table 2) which guarantees the performance of identical technical patterns.

Table 2.
Mean values ± standard deviation of mechanical responses in squat exercise. Differences and confidence intervals (95% CI), p-values and effect sizes (ES) are also reported

| | SWU | GSWU | SWU vs. GSWU | | |
|---|---|---|---|---|---|
| | | | Mean ± CI (95%) | p | ES |
| MPV [set 1] ($m.s^{-1}$) | 0.66 ± 0.07 | 0.68 ± 0.07 | 0.02 ± 0.05 | 0.41 | 0.40 |
| MPV [set 2] ($m.s^{-1}$) | 0.63 ± 0.05 | 0.64 ± 0.07 | 0.01 ± 0.06 | 0.61 | 0.19 |
| MPV [set 3] ($m.s^{-1}$) | 0.63 ± 0.06 | 0.62 ± 0.09 | -0.01 ± 0.07 | 0.60 | 0.15 |
| MPVmin total ($m.s^{-1}$) | 0.46 ± 0.11 | 0.48 ± 0.08 | 0.01 ± 0.10 | 0.53 | 0.19 |
| MPVmax total ($m.s^{-1}$) | 0.67 ± 0.06 | 0.68 ± 0.06 | 0.01 ± 0.04 | 0.59 | 0.23 |
| VL [set 1] (%) | 19.89 ± 8.47 | 22.12 ± 10.22 | 2.23 ± 6.88 | 0.28 | 0.32 |
| VL [set 2] (%) | 23.47 ± 12.02 | 19.92 ± 12.03 | -3.55 ± 9.42 | 0.21 | 0.38 |
| VL [set 3] (%) | 24.54 ± 14.84 | 21.25 ± 8.87 | -3.29 ± 16.33 | 0.50 | 0.20 |
| VL [total] (%) | 31.43 ± 15.86 | 29.66 ± 10.14 | -1.77 ± 15.17 | 0.69 | 0.23 |
| PV [set 1] ($m.s^{-1}$) | 1.15 ± 0.12 | 1.17 ± 0.08 | 0.02 ± 0.06 | 0.31 | 0.27 |
| PV [set 2] ($m.s^{-1}$) | 1.12 ± 0.08 | 1.13 ± 0.09 | 0.01 ± 0.05 | 0.85 | 0.27 |
| PV [set 3] ($m.s^{-1}$) | 1.08 ± 0.15 | 1.11 ± 0.10 | 0.03 ± 0.11 | 0.41 | 0.25 |
| PV [total] ($m.s^{-1}$) | 1.15 ± 0.09 | 1.17 ± 0.08 | -0.01 ± 0.04 | 0.75 | 0.25 |
| Time to PV [set 1] (s) | 649.66 ± 182.20 | 733.08 ± 140.41 | 84.14 ± 240.75 | 0.25 | 0.26 |
| Time to PV [set 2] (s) | 711.50 ± 185.11 | 642.91 ± 234.79 | -68.59 ± 311.23 | 0.46 | 0.17 |
| Time to PV [set 3] (s) | 726.25 ± 120.46 | 699.33 ± 185.22 | -26.91 ± 223.58 | 0.68 | 0.12 |
| Displacement [set 1] (m) | 0.61 ± 0.06 | 0.62 ± 0.05 | 0.01 ± 0.05 | 0.31 | 0.21 |
| Displacement [set 2] (m) | 0.60 ± 0.07 | 0.61 ± 0.08 | 0.01 ± 0.03 | 0.54 | 0.35 |
| Displacement [set 3] (m) | 0.60 ± 0.07 | 0.61 ± 0.06 | 0.01 ± 0.04 | 0.57 | 0.23 |
| MPP [set 1] (W) | 410.25 ± 68.46 | 412.95 ± 82.79 | 2.70 ± 38.15 | 0.81 | 0.10 |
| MPP [set 2] (W) | 390.05 ± 69.27 | 392.83 ± 72.39 | 2.78 ± 35.85 | 0.79 | 0.10 |
| MPP [set 3] (W) | 387.35 ± 63.78 | 379.79 ± 78.26 | -7.56 ± 42.16 | 0.54 | 0.17 |
| MPPmin total (W) | 280.21 ± 79.49 | 295.30 ± 80.24 | 15.09 ± 75.21 | 0.50 | 0.20 |
| MPPmax total (W) | 415.76 ± 68.40 | 416.40 ± 80.00 | 0.63 ± 28.76 | 0.94 | 0.02 |
| MPP [total] (W) | 6286.25 ± 1117.81 | 6343.44 ± 1430.44 | 57.19 ± 689.34 | 0.77 | 0.08 |

SWU: Specific warm-up; GSWU: general plus specific warm-up; MPV: mean propulsive velocity; MPVmin total: mean propulsive velocity minimum total; MPVmax total: mean propulsive velocity maximum total; VL: velocity loss; VL [total]: velocity loss total; PV: peak velocity; Time to PV: time to peak velocity; Displacement: exercise displacement; MPP: mean propulsive power; MPPmin total: mean propulsive power minimum total; MPPmax total: mean propulsive power maximum total. MPP total: mean propulsive power total.

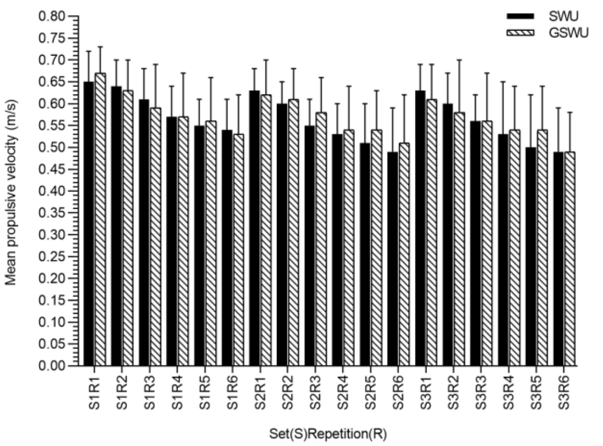


Figure 2. Mean propulsive velocity values in each repetition performed during squat resistance training session. Values obtained in the six repetitions (R) during the first, second and third sets (S) of specific warm-up (SWU) and general plus specific warm-up (GSWU)

In the physiological variables, differences were found in the HR between the SWU and the GSWU after the warm-up in the bench press resistance training (HR during SWU: 100.00 ± 16.93 bpm and HR during GSWU: 110.57 ± 9.69 bpm, *p*= 0.03, ES= 0.65, moderate effect). No differences were reported in the other physiological and psychophysiological variables in the bench press and the squat resistance training (Figure 3).

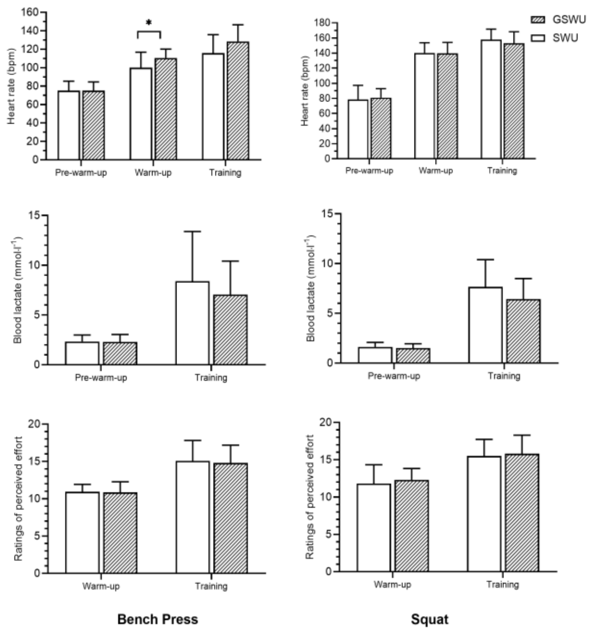


Figure 3. Physiological (heart rate and blood lactate concentration) and psychophysiological (rating of perceived effort) variables of specific warm-up (SWU) and general plus specific warm-up (GSWU) in bench press and squat resistance training before warm-up, after warm-up and after the resistance training session. * $p < 0.05$

## Discussion

The present study aimed to compare the effects of two different warm-up strategies, specifically, SWU and GSWU, on the mechanical responses of force production in the bench press and squat resistance exercises during resistance training. No differences were observed between the two conditions (i.e., GSWU and SWU) either for the bench press resistance training or the squat resistance training, which did not confirm our hypothesis. These results suggested that the general warm-up followed by a specific warm-up or just a specific warm-up can both be used as preparatory activities for bench press and squat resistance training performances.

The role of resistance performance is unequivocal to the exercise related to competitive movement, as well as to the components related to physical fitness, such as the ability to perform daily activities (Garber et al., 2011). In this sense, the preparation for a competitive event or training session can determine the success or failure of practitioners in achieving their goals. Increasing strength performance and optimizing resistance training should be a primacy for athletes, coaches, and sports scientists. In this sense, warm-ups could be helpful to optimize performance (Wilcox et al., 2006). However, there is a controversy on the use of general warm-up when applied before resistance training. Some authors reported that general warm-up may impair the development of power (Wilson et al., 2013), while others revealed positive results on muscle force production using a combination of general with specific warm-up (Abad et al., 2011). Considering the specific warm-up, Weineck (1991) highlighted the importance of including exercises that aim to warm-up the muscles that are directly related to the sport to be performed. Fermino et al., (2008) also explained that specific warm-ups can provide increases in the speed of contraction and relaxation of muscles, as well as increase the mechanical efficiency of muscle contraction due to the decreased viscosity at the cellular level. Costa (2014) investigated the acute effect of specific warm-up before resistance training and the results showed a significant increase in strength values for leg press exercise.

In the present study, no differences were found in the mechanical variables between GSWU and SWU during bench press or squat resistance training sessions. This may be explained by the small stimuli caused by the general warm-up component that was implemented (i.e., 10 minutes of treadmill running at 70% of heart rate reserve). This explanation was first addressed by Gil et al. (2016) after they found no differences between the use of a general warm-up followed by a specific warm-up or a specific warm-up only in the 1RM values of leg press and bench press exercises. On the opposite, Abad et al. (2011) suggested that including a general warm-up before the specific one induced neuromuscular adjustment that increased muscle force production capacity and resulted in higher 1RM values in leg press exercise. These contradictory facts can be explained by the different methodologies used by the different studies (i.e., testing protocols, exercise used, and variables assessed). It is important to highlight that, in the current study, no discrepancies were identified in the bar displacement, both in the bench press and squat resistance training sessions, between warm-ups. Considering that the range of motion can significantly affect muscle activity and barbell velocity (Krzysztofik et al., 2021), the non-existence of differences in the bar displacement between conditions ensures that the range of motion was maintained between sessions.

A general warm-up is expected to raise body temperature, oxygen uptake, and heart rate, contributing influence oxygen diffusion in the muscles (Nicoli et al., 2007). Examining the physiological changes induced by warm-up in the current study, the combination of general warm-up plus specific warm-up caused a higher response of HR, with increased values when compared to the specific warm-up. This difference was found in the bench press but not in the squat resistance training session. The squat exercise is known to require more muscle mass recruitment and cause a higher acute hemodynamic and metabolic response than the bench press (Andrade et al., 2022). This way, when performing the squat SWU, it is expected that the HR raise more than a bench press, leading to trivial effects of additional general warm-up. However, in the bench press exercise, the inclusion of a general warm-up led to increased HR response after the warm-up, perhaps because of the lack of stimuli caused by the SWU. Nevertheless, the blood lactate concentration and the RPE values were not different between the GSWU and the SWU, in both exercises. These physiological and psychophysiological responses were probable, considering the non-existence of differences in the resistance training performances, and according to recent findings (Ushirooka et al., 2023). We can hypothesize that the differences between the two warm-ups (i.e., adding a general warm-up before the specific warm-up) were not enough to cause a detectable metabolic effect.

Some limitations should be addressed in the current study: i) one should be aware that only bench press and squat exercises were analyzed, therefore caution should be taken when generalizing the present findings to other resistance training exercises. Nonetheless, both exercises are two of the most used exercises in strength-related studies and resistance training contexts; ii) a small sample of men was used in the study, and a larger sample of both sexes would provide clearer conclusions in some of the analyzed variables and support the effects of different warm-ups approaches in males and females; iii) one should acknowledge possible unknown variation in day-to-day performance, despite the counterbalanced distribution of the participants. Further research should analyze additional variables such as hormonal responses and core temperature, which seem to be pertinent and helpful to better understand the effects of different warm-up routines in the selected resistance exercises' performance.

## Conclusion

The current study revealed that GSWU or SWU can both be used as preparatory activities for bench press and squat resistance training sessions. Notoriously, the general warm-up can positively influence muscle force production, and positive results in resistance training sessions of the bench press and the squat exercises can be obtained using the GSWU or just SWU. However, if the participant needs to do a shorter training due to limited training time, it seems more useful to do a specific warm-up instead of a general one with a specific warm-up. These findings may be useful to professionals (i.e., coaches, strength and conditioning specialists, sports scientists) in providing appropriate warm-up strategies to maximize resistance training.

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