Article

Effect of different types of warm-up on strength and skin temperature of Paralympic powerlifting athletes

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Abstract: (1) Background: The aim of the present study was to evaluate the effect of different types of warm-ups on the strength and skin temperature of Paralympic powerlifting athletes; (2) Methods: The participants were 15 male Paralympic powerlifting athletes. It was analyzed the effects of three different types of warm-up (without warm-up (WW), traditional warm-up (TW), or stretching warm-up (SW)) on static and dynamic strength tests as well as in the skin temperature, which was monitored by thermal imaging; (3) Results: show no differences in the dynamic and static indicators of the force in relation to the different types of warm-up. No significant differences were found in relation to the Peak Torque ($p = 0.055$, $F=4.560$, $\eta 2p= 0.246$ medium effect), and 1-Repetition Maximum ($p = 0.139$, $F=3.191$, $\eta 2p = 0.186$, medium effect) between the different types of warm-up. In the thermographic analysis, there was a significant difference only in the Pectoral muscle clavicular portion between the TW (33.04 ± 0.71ºC) and the WW (32.51 ± 0.74ºC) ($p = 0.038$). The TW method also presented slightly higher values than the SW and WW in the Pectoral Muscles Sternal portion and in the Deltoid anterior portion, but with p-value > 0.05; (4) Conclusions: that the types of warm-up studied do not seem to interfere with the performance of Paralympic Powerlifting athletes. However, the thermal images showed that traditional warm-up best meets the objectives expected for this preparation phase.

Keywords: *warm up, muscle force, performance, resistance training, thermal imaging, physiology*

1. Introduction

Physical activity has been described as an important way to promote physical and psychosocial health [1,2,3], in special groups [4,5,6,7,8,9,10,11] and disabled people [12]. Among physical activities, strength training has gained greater attention with several studies indicating better physical and psychosocial indicators [13,14,15]. On the other hand, strength training with the intention of competition has been promoted with disabled people and with improvements in physical parameters [12,16].

Among the strength sports, the Paralympic Powerlifting (PP) has been gaining more and more followers, and the sport aims to lift the greatest possible load in the adapted bench press [16,17,18]. However, the studies have focused more on aspects of health, classification and etiology of injuries [12,19,20]. On the other hand, few studies have addressed aspects related to performance [18,21,22,23].

When addressing the issue of performance in adapted sports and the Powerlifting Paralympic, the warm-up is presented as essential for performance [24]. Warming aims at improving nerve conduction, allied to an increase in temperature [25,26]. The specific warm-up has been shown to improve strength [27,28,29], however, variations in the type of warm-up can be harmful [30]. Currently, there is no consensus between the effect of different types of warm-ups [29,31,32].

Therefore, the aim of the present study was to evaluate the effect of different types of warm-ups on the strength and skin temperature of Paralympic powerlifting athletes. It was hypothesized that the warm-up methods are not capable of altering the performance of paralympic powerlifting athletes.

2. Materials and Methods

2.1. Sample

Fifteen male Paralympic powerlifters volunteered for this study. Every participant was a competitor involved in national competitions and were eligible for this sport under the International Paralympic Committee. Participants were required to have participated in a minimum of one competition at the national level over the past 12-month period and average prior experience in the sport was 2.43 ± 1.03 years. The participants mean age and body mass was 28.47 ± 5.79 years and 81.75 ± 17.33 kg, respectively. Body mass was assessed with specific adapted equipment as described Resende et al., [32].

2.2. Experimental Design

The study comprised 3 weeks which included 9 sessions separated by a minimum of 48-h. The first three sessions (week 1) were dedicated to baseline measurements of thermal images on session 1, and to familiarization with the dynamic strength tests on sessions 2 (1-RM and mean propulsive velocity) and the isometric strength tests on session 3 (impulse, variability, peak torque). In week 2 (sessions 4 to 6), the subjects performed in random order the three experimental conditions herein (3 types of warm-up) followed 10-min later by the dynamic strength tests [33]. Skin temperature was measured immediately post-warm-up. In week 3 (sessions 7 to 9), the subjects performed in random order the three experimental conditions herein (3 types of warm-up) followed 10-min later by the isometric strength tests.

All testing was performed in an acclimated room, at the same time of day for and under the same environmental conditions (23 °C to 25 °C of temperature and relative humidity of ~60%). The athletes were asked to maintain the same routine during the evaluation days, avoiding strenuous exercise and refraining from consuming caffeine for 48-h before the test.

The three types of exercise condition in terms of warm-up were: i) exercise without any previous warm-up; ii) exercise after traditional warm-up (which included dynamic resistance exercises); and iii) exercise after a stretching warm-up (including 3 exercises as shown on figure 1). Full explanation of the three types of war-up is described elsewhere [32,34].

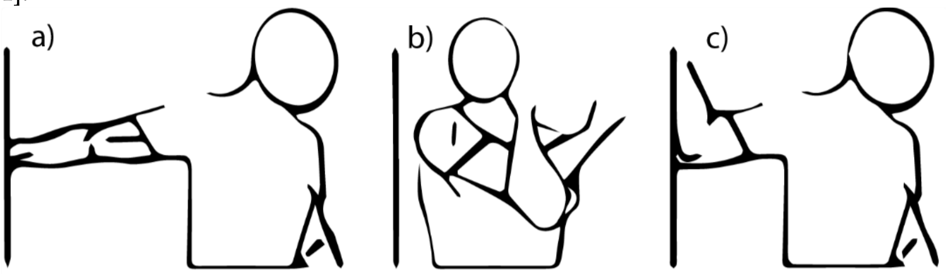

Figure 1. Stretches used as a warm-up method (A) shoulder, (B) triceps and (C) pectoralis major

2.3. Procedures

Skin temperature measurement

Thermal images acquisition was performed in a room prepared without natural light, with no airflow directed to the collection site, in ambient temperature conditions maintained around 24°C ± 1°C and relative humidity around 50% by means of an air conditioner and monitored by a hygrometer (HIGHMED, model HM-01, USA) [11,13].

Subjects were instructed not to perform vigorous physical activity in the previous 24 hours, not to consume alcohol or caffeine, and not to use any type of cream or lotion on the skin in the 6 hours immediately prior to the evaluation. To obtain the thermograms, the athlete remained seated and did not make sudden movements, did not cross the arms, and did not scratch for a period of at least 10 minutes for acclimatization [13,35].

Images were captured by an infrared camera model FLIR T640sc (Flir, Stockholm, Sweden) measuring range −40 °C to 2000°C, accuracy 2%, sensitivity < 0.035, infrared spectral band of 7.5–14 μm, refresh rate of 30 Hz, resolution of 640 × 480 pixels. The software used for thermal image analysis was FLIR TOOLS (Flir, Stockholm, Sweden). The region of interest evaluated was the anterior and posterior faces of the trunk and arms [13,36,37]. Figure 2 presents an illustration of the thermal images acquired.

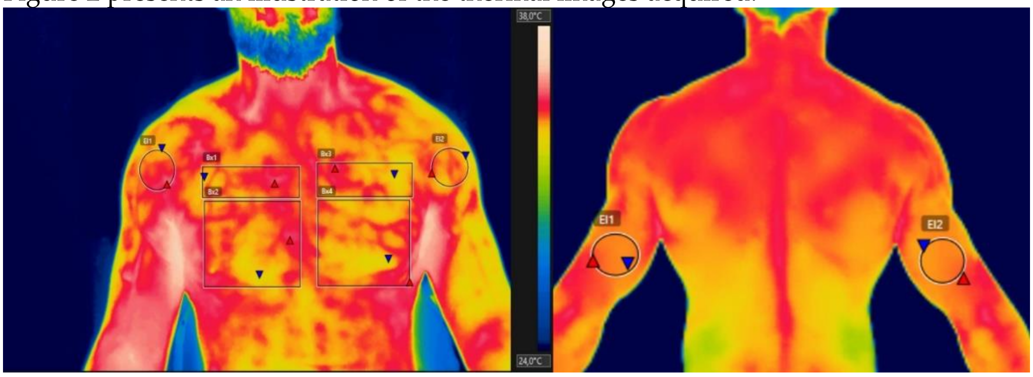

Figure 2. Illustration of the Regions of Interest (ROI) in the thermal images acquired.

Dynamic strength measurements (1-RM and mean propusive velocity)

In every testing herein, a 2.1 m long official adapted bench (Eleiko Sport AB, Halmstad, Sweden), approved by the International Paralympic Committee [38] was used. The barbell was a 2.2 m long, 20 kg weight official bar (Eleiko Sport AB, Halmstad, Sweden). 1- RM assessment in bench press exercise was performed following the protocol proposed by Fleck and Kraemer [39]. A 3- to 5-min rest was provided between attempts. To measure the speed of movement, a valid and reliable [40] linear position transducer (Chronojump, BoscoSystem, Barcelona, Spain) was attached to the bar. The maximum speed averages were collected with the 1-RM load [41].

Isometric Force measurements (impulse, variability and peak torque)

Isometric evaluation was performed by having the subjects pressing the bar at a distance of 15 cm from the chest. Impulse, variability and peak torque (PT) were measured with the help of a force sensor (Chronojump, BoscoSystem, Barcelona, Spain) and a goniometer FL6010 (Sanny, São José dos Campos, Brazil). Details of this testing can be found elsewhere [32].

2.4. Statistical Analysis

After confirmation of normality and homogeneity assumptions, one-way ANOVA with Bonferroni's post hoc was performed to compare the measurements post- the three types of warm up. A repeated-measures analysis of variance was used to evaluate the performance between the warm up conditions, followed by Bonferroni post hoc comparison tests. To check the effect size partial Eta squared (η2p) was used, adopting values of low effect (≤0.05), medium effect (0.05 to 0.25), high effect (0.25 to 0.50), and very high effect (>0.50) for ANOVA [42]. A d value <0.2 was considered a trivial effect, 0.2 to 0.6 a small effect, 0.6 to 1.2 a moderate effect, 1.2 to 2.0 a large effect, 2.0 to 4.0 a very large effect, and ≥4.0 an extremely large effect [43]. Cohen d was calculated as the difference between the mean divided by the pooled SD to estimate the effect size for between-lift comparison [42]. All statistical analyses were performed using the computerized package Statistical Package for the Social Science (SPSS)version 22.0(IBM Corp, Armonk, NY, USA). The level of significance was set at $p< 0.05$. Data is presented as means (X) ± standard deviation (SD) and 95% confidence interval (95% CI).

3. Results

The participants 1-RM in bench press was 119.07 ± 43.15, which corresponded to a mean of 1.50 ± 0.38 times their body mass. Values above 1.4 (1RM / body weight) in the bench press, are considered to classify elite athletes [44].

The results found in the dynamic indicators of force, MPV and Power, and static, Impulse and Variability in relation to the different types of warm-up are shown in table 1.

Table 1: Dynamic and static force indicators (mean ± standard deviation, 95% CI) in relation to different types of Warm up.

Warm up	MPV (m.s-1) X ± DP (IC 95%)	Power (W) X ± DP (IC 95%)	Impulse(N.s) X ± DP (IC 95%)	Variability (N) X ± DP (IC 95%)
Without Warm up	0,12±0,06 (0,09-0,16)	137,69±90,80 (87,41-187,97)	4022,23±1341,43 (3279,36-4765,09)	46,74±30,06 (30,10-63,38)
Traditional	0,11±0,05 (0,09-0,14)	128,86±69,70 (90,26-167,46)	3964,91±1240,10 (3278,17-4651,66)	40,57±17,72 (30,76-50,38)
Stretching	0,10±0,04 (0,07-0,12)	105,77±50,77 (77,65-133,88)	3740,41±1114,96 (3122,96-4357,85)	41,26±23,42 (28,29-54,22)
P	0.272	0.383	0.293	0.999
η2p	0.122##	0.116##	0.121##	0.030#

* $p< 0.05$ (ANOVA two-way, and Bonferroni Post Hoc).# Low Effect, ## Medium Effect
MPV: Mean Propulsive Velocity.

Table 3 shows that there were no differences in the dynamic and static indicators of the force in relation to the different types of warm-up. The results found for Peak Torque (Nm) and 1 Maximum Repetition (kg) are shown in Figure 3.

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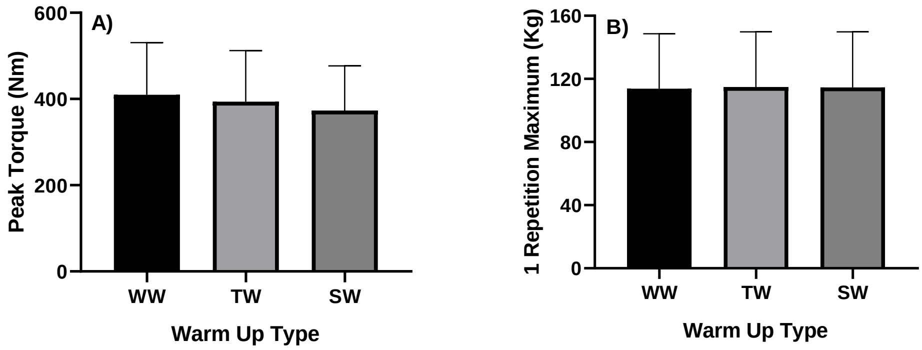

Figure 3. Evaluation of A) Peak Torque (N.m) and B) 1 Repetition Maximum (Kg), with different types of warm up. WW: without warm up, TW: traditional warm up and SW: stretching warm up.

No significant differences were found in relation to the A) Peak Torque (p = 0.055, F=4.560, η2p= 0.246 medium effect), and B) 1 Repetition Maximum (p = 0.139, F=3.191, η2p = 0.186, medium effect) between the different types of warm up.

Table 3. Skin Temperature over active muscles in different types of Warm-Up (Mean ± SD and CI 95%).

Muscles	WW (ºC)	TW (ºC)	SW (ºC)	WW vs. TW	WW vs. SW	TW vs. SW	p-value	ηp2
Pectoral	31,77±1,18	32,23±0,80	32,06±1,09	p = 0.238	p =0.505	p = 0.642	0.261	0.091a
Sternal	(31,11-32,42)	(31,79-32,68)	(31,45-32,67)	d =0.456	d =0.255	d =0.178		
Pectoral	32,51±0,74*	33,04±0,71*	33,02±0,55	p = 0.064	P =0.049*	p = 0.934	0.038*	0.276b
Cavicular	(32,10-32,92)	(32,65-33,43)	(32,72-33,32)	d =0.731	d =0.782	d =0.031		
Anterior	32,31±0,69	32,52±0,78	32,64±0,60	p = 0.457	p =0.230	p =0.061	0.145	0.099a
Deltoide	(31,93-32,69)	(32,09-32,95)	(32,31-32,97)	d =0.285	d =0.465	d =0.741		
Triceps	31,47±0,93	31,99±0,54	32,01±0,80	p = 0.082	p =0.112	p =0.939	0.108	0.193a
	(30,96-31,99)	(31,70-32,29)	(31,57-32,46)	d =0.684	d =0.623	d =0.029		

* p< 0.05 (ANOVA). (WW in comparison with TW). ηp2 = partial eta square. "a": medium effect and "b": high effect. d: Cohen' d. WW: without warm up, TW: traditional warm up and SW: stretching warm up

4. Discussion

The objective of our study was to evaluate the different types of warm-up, without warm-up, traditional warm-up and warm-up with stretching, on thermography and strength indicators. The results of the mean propulsive velocity (MPV) did not show differences between the types of warm-up, however the condition without warm-up (WW) was the one that presented the highest average propulsive speed (1.12 ± 0.06 ms-1), followed by traditional warm-up (TW) (0.11 ± 0.05 ms-1), and warm-up with stretching (SW) (0.10 ± 0.04 ms-1).

A study that evaluated the influence of specific warm-up on strength performance, found that participants were able to achieve a higher propulsive speed in the second and third sets in the squat, and with a tendency to decrease propulsive speed in the bench press, and the time for propulsive speed was shorter after warming up with progressive intensity, demonstrating that speed can be affected by warming up, tending to decrease with more activities [29]. In the horizontal bench press, the MPV does not tend to be greater at the beginning of the training, this is explained by the lower muscle mass involved, when compared to other exercises, in addition to being a relatively simple movement [45]. Thus, it seems that a more relaxed muscle tends to establish a higher speed than after a more traditional warm-up. The reduction in movement speed during strength work tends to indicate fatigue [46,47]. On the other hand, stretching exercises for sports training [48], as well as for maximum tests or for competition are highly questionable, and would normally be related to loss of performance [49]. On the other hand, the elapsed time of the warm-up with the use of stretching must observe an interval greater than three minutes and the warm-up continues [34].

The power despite not showing differences between the three types of warm-up, the condition without warm-up showed a higher power (137.69 ± 90.80W), followed by traditional warm-up (128.86 ± 69.70W), and warm-up with stretching (105 , 77 ± 50.77W). If we consider that power is the product of strength by speed, the importance of speed in resistance training, and can be considered very important in the assessment of muscle strength [50,51]. The warm-up, whether traditional or even with pre-activation, aims at increasing the muscle temperature, activation of the motor unit and myofiber water content [52,53]. Moderate to heavy exercises with loads varying between 20-90% of a maximum repetition tend to improve sprint and jump, especially in subjects trained and familiar with the exercise load [54,55]. However, our findings indicate that WW and TW tend to be better than SW. On the other hand, contrary to this, dynamic and static stretching tends to be favorable as a warm-up strategy. In active individuals, dynamic stretching increased the height of the vertical jump. On the other hand, agility tends to be positively impacted by stretching. Dynamic stretching can improve an athlete's power [56].

The same kinetics occurred in relation to the static components of the force, where there were no differences in Impulse, and the WW method obtained the highest value (4022.23 ± 1341.43Ns), followed by TW (3964.91 ± 1240.10Ns) and of the SW (3740.41 ± 1114.96Ns). In the same direction, the participants tested after 6 min of swimming warm up or warm up on land, with 3 repetitions (pull-over at 85% of the maximum of one repetition). Speed, force, acceleration, impulse, rate of force development (RFD) were evaluated. Warm-up on land with higher loads increased RFD (34.52 ± 16.55 vs. 31.29 ± 13.70 N / s; Δ = 9.35%) and stroke rate (64.70 ± 9, 84 vs. 61.56 ± 7.07 Hz; Δ = 5.10%) compared to traditional water warm-up, but decreased speed, strength, acceleration, impulse and power [57]. That is, traditional warm-up can decrease the impulse, and lighter warm-up tends not to decrease the impulse. Likewise, exercises with high load resistance have been used to facilitate the improvement of neuromuscular performance. Traditional warm-up has its use restricted, despite its specificity and practicality for sports performance. Thus, when verifying the effect of repeated exercises on performance, where 43 subjects were evaluated. Performance was quantified through vertical jump, relative thrust, and normalized peak strength at baseline. No improvements were found for the relative impulse in repeated trials, the sixth trial was significantly less than the baseline (2.35 ± 0.38 vs. 2.26 ± 0.35; $p \leq 0.001$). This indicates that the repetition of traditional warm-ups can lead to fatigue, which tends to interfere with performance [58].

In variability, although there are no differences between the types of warm-up, the least variability was TW (40.57 ± 17.72N), followed by SW (41.26 ± 23.42N) and WW (46, 74 ± 30.06N). This may indicate that traditional warm-up tends to promote a more stable situation on a muscular level than other types of warm-up, noting however that there were no significant differences between the warm-up methods.

There were also no differences in Peak Torque, however the WW method showed higher values (409.58 ± 120.99Nm), followed by TW (393.74 ± 118.48Nm) and SW (373.14 ± 103.51Nm). One study evaluated standard warming or dropjump (plyometric protocol) or a slow walk (control protocol). Post-activation potentiation was assessed by changes in isometric muscle contractions. The plyometric protocol increased the peak contraction torque (PTT), the rate of torque development (RTD) and the impulse significantly (by 23, 39 and 46%, respectively). Peak contraction torque, RTD and impulse decreased significantly after standard warm-up. Thus, standard warming did not enhance, but may have reduced, the muscle's ability to generate strength [59]. The data in this study contradict our findings.

In the 1RM test, the three methods also showed no differences, however the TW method (114.80 ± 34.98 kg), showed higher values, followed by the SW (114.53 ± 35.20 kg) and the WW (113.80 ± 34.80 kg). A specific warm-up can increase the production of strength after maximum or almost maximum muscle stimulation [31]. The effects of warming on athletic success have gained great attention in recent studies. Authors [32] evaluated different types of warm-up, with the participation of 15 elite Brazilian male athletes from Paralympic Powerlifting (age, 24.14 ± 6.21 years; body weight, 81.67 ± 17.36 kg). A significant difference was observed for the maximum isometric strength, in the without warm-up (WW) in relation to traditional warm-up (TW) and stretching warm-up (SW) ($p = 0.005$, $\eta 2p = 0.454$, high effect). On the other side, no significant differences were observed in the RFD, fatigue index (FI), and time in the different types of warm-up ($p > 0.05$). No significant differences were observed in relation to the maximum repetition ($p = 0.121$, $\eta 2p = 0.275$, medium effect) or the maximum speed ($p = 0.712$, $\eta 2p = 0.033$, low effect) between the different types of warm-up. The different warm-up methods do not seem to provide significant differences in strength indicators in this population, and this could be explained by the displacement they use to the upper limbs, the target of the study [32].

In thermographic analysis, there was significant difference only in the Pectoral muscle clavicular portion between the TW (33.04 ± 0.71ºC) and the WW (32.51 ± 0.74ºC) ($p = 0.038$). The TW method also presented slightly higher values than the SW and WW in Pectoral Muscles Sternal portion and in Deltoid anterior portion, but with p value > 0.05. These results are in agreement with authors who studied thermal response to resistance training [60,61]; since traditional warm-up involves specific resistance exercises for the primary muscles that are recruited in the main work.

The physiological reason for the increase in skin temperatures observed in the Pectoral muscle clavicular portion (TW protocol) might be the increase in the recruitment of motor units, which occurs during the traditional warm-up, needed to prepare the muscles for the considerable effort needed to overcome the weight of the barbell and give it acceleration [62].

Authors [60,61] reported an increase in skin temperature over the muscles that were the main responsible for the movement requested, after the exercise. Neves et al., [37] report that the warming of ROI in arm exercise seems to be related to exercise volume. In this sense, since the traditional warm-up protocol included a large volume of exercises, it promoted an increase in blood flow to the Pectoral muscle clavicular portion and, consequently, greater heat dissipation by the skin over this muscle.

The study used the functional classification adopted by the International Paralympic Committee. Thus, it can be mentioned as limitations of this study the control of variables such as balance, food, and life habits.

5. Conclusions

It can be concluded that the type of warm-up does not seem to interfere with the performance of Paralympic Powerlifting athletes. However, although there are no significant differences between the warm-up methods, the thermal images showed that traditional warm-up best meets the objectives expected for this preparation phase and that in a competition it could be enough to provide better performance and classification.

The results found may have been influenced by the condition of being in a wheelchair and requiring the use of the muscles of the upper limbs and trunk for displacement, thus promoting the maintenance of these muscle groups in a state of activity similar to what is observed after the warm-up protocols.

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