Combined active and passive warm-ups as a technique to increase the number of deep squat repetitions

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doi: 10.18176/archmeddeporte.00123

Received: 26/07/2022
Accepted: 15/11/2022

Summary

The aim of this study was to determine if the combination of active (exercise) and passive warm-up (thermal blanket) generates an increase in the number of deep squat repetitions compared to only active warm-up. Ten physically active and apparently healthy subjects (26.2 ± 5.9 years of age) were recruited for the study. Four sessions, with three-days intervals were performed. In the first session the maximum weight in deep squat was estimated (Brzycki's formula), the second, third and fourth sessions performed the greatest number of deep squat repetitions with 85% maximum repetition (to exhaustion or even losing the technique). Before each condition, subjects were randomly assigned to one of three different conditions: active warm-up (CA_{ct}) traditional warm-up plus five minutes sitting, active warm-up plus placebo (CA_{ct+P}) traditional warm-up plus five minutes sitting with thermal blanket placed on the legs and combined warm-up (CC_{om}) traditional warm-up plus five minutes with a thermal blanket placed on the legs. No differences ($p > 0.05$) were found between CA_{ct} (8.6 ± 1.8 reps) and CA_{ct+P} (8.7 ± 1.6 reps) conditions in the number of squats performed. However, the CC_{om} condition (11.1 ± 2.0 reps; $p = 0.001$; $d = -2.107$) was more effective compared to CA_{ct} (8.6 ± 1.8 reps) and CA_{ct+P} (8.7 ± 1.6 reps). A combination of active and passive heating (thermal blanket), increases the number of repetitions of deep squats in physically active young people.

Key words:
Heating pad. Lower body. Physical performance.

La combinación de calentamiento activo y pasivo como método para incrementar la cantidad de repeticiones de sentadilla profunda

Resumen

El objetivo del estudio fue determinar si la combinación del calentamiento activo (ejercicio) y pasivo (almohadilla térmica) genera un aumento en la cantidad de repeticiones de sentadilla profunda en comparación a realizar únicamente calentamiento activo. Para el estudio se reclutaron 10 sujetos físicamente activos y aparentemente sanos (26,2 ± 5,9 años de edad). Se realizaron cuatro sesiones con intervalos de tres días por sesión. En la primera sesión se estimó el peso máximo, mediante repetición máxima, en sentadilla profunda (fórmula de Brzycki), la segunda, tercera y cuarta sesión realizaron la mayor cantidad de repeticiones de sentadilla profunda con el 85% de la repetición máxima (al fallo o hasta perder la técnica). Los sujetos fueron asignados de forma aleatoria a una de tres condiciones distintas: calentamiento activo (CA_{ct}, calentamiento tradicional más cinco minutos sentados), calentamiento activo más placebo (CA_{ct+P}, calentamiento tradicional más cinco minutos sentados con almohadilla térmica apagada sobre las piernas) y calentamiento combinado (CC_{om}, calentamiento tradicional más cinco minutos con la almohadilla térmica encendida sobre las piernas). No se hallaron diferencias ($p > 0,05$) entre la condición CA_{ct} (8,6 ± 1,8 rep) y CA_{ct+P} (8,7 ± 1,6 rep) en la cantidad de sentadillas realizadas. Sin embargo, la condición CC_{om} (11,1 ± 2,0 rep; $p = 0,001$; $d = -2,107$) mostró ser más efectiva en comparación a CA_{ct} (8,6 ± 1,8 rep) y CA_{ct+P} (8,7 ± 1,6 rep). La combinación de calentamiento activo y pasivo (ejercicio y con almohadilla térmica) incrementa la cantidad de repeticiones de sentadilla profunda en personas jóvenes físicamente activas.

Palabras clave:
Almohadilla térmica. Tren inferior. Rendimiento físico.

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Introduction

Regardless of the type of physical exercise or sport, warming up is a fundamental part of the training session or competition and can even be considered to be an essential activity during exercise or competition. However, its effect on physical performance is still at issue[1-4].

Warming up is considered to be any activity that results in an increase in body temperature. It may be performed actively and/or passively in order to improve neuromuscular response and reduce the probability of injury[5]. Active warm-up is achieved through physical exercise (aerobic and/or anaerobic) while passive warm-up refers to the use of some external means to raise the body temperature (hot water immersion, increase of environmental temperature, compression sleeves, heating pads, among others)[6].

Today, it is highly recommended to perform an active warm-up routine prior to a sports activity due to the improvement in physical performance caused by the muscular metabolism and the muscle fibre conduction velocity, as well as generating greater emotional stability, confidence and mental preparation[4,6,7]. Likewise, passive warming-up has been shown to be beneficial in improving the joint range of motion and reducing the probability of injury[8,9].

It has been demonstrated that the increase in body temperature, through a passive warm-up, improves physical performance in activities of short and long duration due to the increase in the muscular metabolism and the degradation of glycogen, production of adenosine triphosphate and phosphocreatine. Furthermore, it increases the muscle fibre conduction velocity, in other words it generates an increase in muscle power caused by the rapid release of calcium from the sarcoplasmic reticulum and the hyperpolarization of the membrane as a result of the increased activity of the sodium-potassium pump. Another factor that increases physical performance is muscle relaxation, which improves at high temperatures (25-37 °C) due to the efficiency of the mechanisms for the removal of calcium from the sarcoplasm, calcium-troponin dissociation and the separation of the actin-myosin bridges[10,11].

In the case of an active warm-up, apart from the mechanisms mentioned above, it also drives the oxygen uptake kinetics due to a greater gas exchange, to a change in the oxyhemoglobin curve and to the activation of the oxidative enzymes. It also improves post-activation potentiation, in other words, intense muscle activity generates greater force in the subsequent exercise. The above is the result of an increase in the electrical activity in the spinal cord, increased actin filament calcium sensitivity and an increase in the calcium concentrations in these muscle fibres[4].

Considering the benefits of warming up on physical performance, the purpose of this study was to determine whether the combination of an active and passive warm-up (heating pad) leads to an increase in the number of deep squat repetitions (85%RM) compared to solely active warm-up.

Material and method

Participants

10 subjects were recruited (5 men and 5 women), who were physically active and apparently healthy (age 26.2 ± 5.9 years, weight 70.0 ± 11.8 kg, height 166.6 ± 10.9 cm), with 2.8 ± 1.4 years of experience performing deep squat exercises. Subjects were selected non-probabilistically for convenience. All participants were informed in detail with regard to the objectives and procedures of the study, emphasising the risks involved. This was set out in a letter of informed consent and voluntary participation signed by each participant. The investigation protocol was developed in compliance with the guidelines for investigations on human beings established in the declaration of Helsinki[12].

Procedure

The subjects attended a fitness centre on four separate occasions. At the first session, an estimation was made of the maximum deep squat weight (75.4 ± 26.9 kg) using the formula proposed by Brzycki[13], weight lifted in kg / (1.0278-0.0278)* number of repetitions). For this test the subjects performed a conventional warm-up focussed on two key aspects: low-intensity aerobic activity (15 seconds of sideways head movements, shoulder rotation, hip rotation, knee flexion-extension, ankle circling in the air and jogging for 3 minutes) and dynamic muscle stretching (pectoralis major, latissimus dorsi, hamstrings, quadriceps and iliopsoas, 15 sec. each)[14].

Once the maximum squat weight had been estimated, the order of the following three conditions was randomly assigned, consisting in performing the greatest number of deep squat repetitions at 85% of their estimated maximum capacity in session one (64.1 ± 22.9 kg) (Figure 1). It should be mentioned that all the subjects attended together at the same time (8:30 to 10:30 h) with a 3-day interval between sessions.

Combined warm-up (CC_{om})

For this condition, the subjects performed the active warm-up indicated in session one. They subsequently sat down and a pad heated to 42°C was placed on their legs (GAON Innovación, State of Mexico, Mexico) (Figure 2) for a period of five minutes. At the end of the five minutes, the skin temperature was 37.4 ± 1.0°C.

Active warm-up (CA_{ct})

The subjects performed the conventional active warm-up of session one, they then sat down for a five-minute period without the heating pad. At the end of this seated period, the skin temperature at the quadriceps was 32.0 ± 1.0°C. The skin temperature was taken with an infrared thermometer, Fluke 68 (Washington, USA), which had a resolution of 0.1°C and an accuracy of ± 1°C.

Active warm-up plus placebo (CA_{ct+P})

PFor this condition, the subjects performed the same active warm-up as for session one. Subsequent to this, they sat down for a five-minute period and a disconnected heating pad was placed on their legs with the temperature control display facing downwards (so that they were unable to see that it was off). This condition was proposed in order

Figure 1. Example of a deep squat.

Figure 2. Example of the application of the heating pad for condition CC_{om} and CA_{ct+P}.

to determine whether the use of the heating pad created a placebo effect on physical performance. At the end of the five minutes, the skin temperature was 32.1± 0.3°C.

The active warm-up intensity was measure subjectively by the Borg Rating of Perceived Exertion (0-10). The subjects rated the warm-up as hard (5.3±1.3). At the end of the seated period, irrespective of the condition, the subjects were instructed to perform the greatest possible number of squats at 85% of maximum weight. For all sessions, the subjects were informed that they should not do any physical exercise in the 24 hours prior to the session, and that they should refrain from consuming medication, drinks and food considered to be diuretic.

Statistical analysis

The SPSS version 23 statistical analysis package was used for the data analysis. Descriptive statistics were used for the variables of age, height, weight and years of experience performing deep squats. The Shapiro-Wilk test of normality gave a normal data distribution ($p > 0.05$). A one-way ANOVA was performed (conditions) on related samples in order to compare the ambient temperature, relative humidity, skin temperature, number of repetitions made and for the sum of the lifted weight (weight multiplied by repetitions) following a warm-up with a heating pad turned on, off and without a heating pad.

Results

No significant differences were found in ambient temperature (CC_{om} 20.0 ± 2.3ºC, CA_{ct} 19.2 ± 5.3 ºC, CA_{ct+P} 20.4 ± 5.5 ºC; $p = 0.91$) or in relative humidity (CC_{om} 59.6 ± 5.9%, CA_{ct} 54.0 ± 5.6%, CA_{ct+P} 49.2 ± 2.8%; $p = 0.41$) between the different conditions. This result indicates that the subjects performed the assessments in the same ambient conditions.

The one-way ANOVA showed no skin temperature differences between condition CA_{ct} and CA_{ct+P} ($p > 0.05$). However, differences were found for condition CCom compared to the other two conditions ($p = 0.001$). These results indicate that the application of the passive warm-up generated an increase in the skin temperature of 5.3°C in comparison to those conditions without this type of warm-up (Table 1).

The variance analysis showed no significant differences ($p > 0.05$; CI95% -1.294, 1.094; $d = -0.079$) between conditions CA_{ct} and CA_{ct+P} in the number of deep squat repetitions made. However, differences were found ($p = 0.001$; CI95% -3.182, -1.618; $d = -2.107$) between CC_{om} and CA_{ct} and between CC_{om} and CA_{ct+P} ($p = 0.001$; CI95% 1.407, 3.593; $d = -2.683$) (Figure 3). The data suggest that the combined warm-up (CC_{om}) leads to a greater number of deep squat repetition (Table 1).

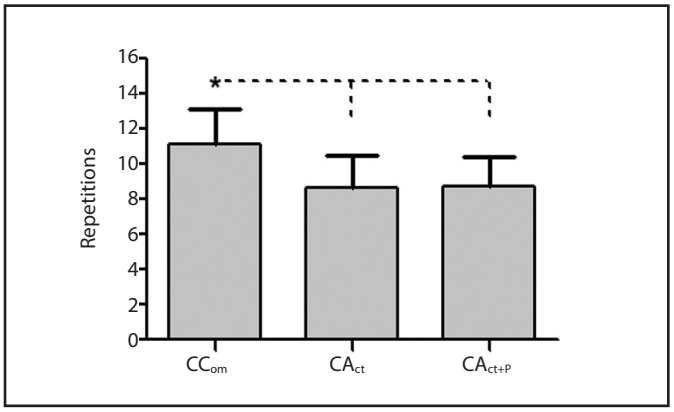
With regard to the total sum of the lifted weight (weight multiplied by repetitions), no differences were found ($p > 0.079$; CI95% -178.329, 8.993; $d = -0.618$) between conditions CA_{ct} and CA_{ct+P}. On the other hand, differences were found ($p = 0.001$; CI95% 137.497, 336.115; $d = 1.469$) between CC_{om} and CA_{ct} and between CC_{om} and CA_{ct+P} ($p = 0.001$; CI95% 91.215, 213.061; $d = 1.055$). This result suggest that the combined warm-

Table 1 Description of the data obtained.

	Skin Temperature (ºC)	Number of repetitions	Sum of lifted weight (kg)
CC_{om}	37.4±1.1*	11.1±2.0*	681.9±167.5*
CA_{ct}	32.0±1.0	8.6±1.8	445.1±154.5
CA_{ct+P}	32.1±0.3	8.7±1.6	529.7±116.4

*Significant differences compared to the other two conditions (p = 0.001).

Figure 3. Number of deep squat repetitions made, comparing the combined warm-up (CC_{om}), active warm-up (CA_{ct}) and active warm-up plus placebo (CA_{ct+P}). * p = 0.001



up (CC_{om}) is the most effective technique for achieving a greater number of squat repetitions (Table 1).

Discussion

The purpose of this study was to determine whether or not the combination of an active and passive warm-up technique (heating pad) leads to an increase in the number of deep squat repetitions (85%RM) compared to solely active warm-up. The key finding was that, with the combined warm-up there was a greater number of squat repetitions compared to the active warm-up and active warm-up with placebo. In other words, combined warm-up enhances physical performance with regard to the number of deep squat repetitions made.

Given that passive warm-up by itself has been demonstrated to be insufficient to put the body through strenuous physical effort, it is therefore necessary to perform active warm-up in order to ensure that the joints and muscle tissue are in optimal condition for greater effort.

For decades it has been reported that one of the principal results of a warm-up session is the increase in body and muscle temperature. According to different authors, a 1ºC increase in muscle temperature is sufficient to observe improvement in the subsequent exercise of between 2-5%[15,16], which was also observed in this study in condition CC_{om}, whereby, although the muscle temperature was not directly measured, a temperature increase was propitiated through the muscle contractions of he active warm-up plus the passive warm-up, increasing the skin temperature by 5.3 °C.

The increase in body temperature through an active or passive warm-up can lead to an increase in the muscular metabolism, muscle fibre conduction velocity and muscle contractile performance[5]. For their part McGowan *et al.*[4], reported that active and passive warm-ups exert a considerable influence on subsequent performance due to an increase in adenosine triphosphate (a nucleotide that is essential in obtaining cellular energy), the actin–myosin cross bridge cycling rate and oxygen uptake kinetics.

Recent investigations report that the combination of active and passive warm-ups improves physical performance compared to when used separately, despite the use of different passive warm-up techniques and application protocols. For example, in their study, Baskaran, Seemathan and Sadhasivam[17] used an infrared lamp to passively increase the body temperature of their subjects, with similar characteristics to those of this study; on the other hand, McGawley, Spencer, Olofsson and Andersson[18], conducted a study with exercise protocols at -7.2 ± 0.2ºC implemented with Alpine skiers who wore a lower-body heated garment as a passive warm-up method. However, when discussing which is the best type of warm-up (active - passive) prior to practising a sport, evidence points to an active warm-up as the most suitable for improving strength, anaerobic power and the range of motion[19,20]. Even so, there is a considerable amount of literature that reports that a warm-up exercise, whether active, passive or combined, is not a factor that improves or negatively affects physical performance, something that is not consistent with the findings of this study. Ahsan and Mohammad[21] reported that there was no difference in muscular strength in any warm-up technique used in their study (active, passive and combined). This could be due to the fact that muscle strength was measured using an isokinetic dynamometer, which measures the strength in the upper extremities, yet the passive warm-up protocol was implemented in the lower body (Gluteus, Hamstrings, Quadriceps, Gastrocnemius, and soleus). Furthermore, the study was on independent samples, analysing volleyball, basketball and handball players, sports in which grip strength may not hold the same importance as explosive strength[22-24]. For their part, Gogte, Srivastav and Balthillaya[25] also reported that they had found no differences in the three different types of warm-up. This could be due to the fact that the active warm-up comprised more intense activities (cycling, leg press, jump squats, squat jumps) than those that are normally part of active warm-up (low-intensity running, for example). Likewise, passive warm-up was implemented through the application of moist towels on the lower limbs for 20 minutes, which is a long period of time in which they do not explain whether the heat was lost or topped up in some way.

Just like the above investigators, Gray and Nimmo[2] found no differences between the active and passive warm-up techniques. This result may have been obtained due to the fact that, in the passive warm-up session, the investigators left the subjects in a climate-controlled room (45°C-70%) until they reached the same body temperature as that

obtained in the active warm-up (36.9±0.2°C). However, the subjects remained seated during the passive warm-up, with no physical exertion, unlike the active warm-up. A further limitation of the studies is that they did not report the muscle, body or skin temperature on completion of the passive warm-up[21-25], which is an important variable for the effectiveness of the warm-up. Unlike the active warm-up, the passive one can increase both the body and muscle temperature without depleting energy substrates. It has been documented that a 1ºC increase in muscle temperature improves physical performance by 2 to 5%[4]. In this study, the subjects increased their leg skin temperature by 5.3ºC with the heating pad, improving their physical performance by 27% with the combined warm-up.

Conclusion

The results of this study demonstrate that the combination of an active and passive (heating pad) warm-up technique increases the number of deep squat repetitions made. However, in order to achieve this improvement, the skin temperature needs to be around 37.5ºC.

Conflict of interest

The authors have no conflict of interest at all.

Bibliography

1. Faghy MA, Brown PI. Whole-body active warm-up and inspiratory muscle warm-up do not improve running performance when carrying thoracic loads. *Appl Physiol Nutr Metab.* 2017;42:810-5.
2. Gray S, Nimmo M. Effects of active, passive or no warm-up on metabolism and performance during high-intensity exercise. *J Sports Sci.* 2001;19:693-700.
3. McCrary JM, Ackermann BJ, Halaki M. A systematic review of the effects of upper body warm-up on performance and injury. *Br J Sports Med*. 2015;49:935-42.
4. McGowan CJ, Pyne DB, Thompson KG, Rattray B. Warm-up strategies for sport and exercise: mechanisms and applications. *Sports Med*. 2015;45:1523-46.
5. Takeuchi K, Takemura M, Nakamura M, Tsukuda F, Miyakawa. Effects of active and passive warm-ups on range of motion, strength, and muscle passive properties in ankle plantarflexor muscles. *J Strength Cond Res.* 2018;35:141-6.
6. Silva LM, Neiva HP, Marques MC, Izquierdo M, Marinho DA. Effects of warm-Up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review. *Sports Med.* 2018;48:2285-99.
7. Park H, Jung M, Park E, Lee C, Jee Y, Eun D, Cha J, Yoo J. The effect of warm-ups with stretching on the isokinetic moments of collegiate men. *J Exerc Rehabil*. 2018;14:78-82.
8. Carlson B, Petushek E, Moore M, Dermyer, H. *Effect of sauna warm-up on overhead squat depth in elite weightlifters.* 33rd International Conference on Biomechanics in Sports; 2015; Poitiers, France.
9. Singh S, Mehta A. Effect of concomitant use of PNF stretching with thermotherapy and massage on plantar flexors flexibility in young females. *Int J Health Rehabil Sci.* 2015;4:84-94.
10. Christensen P, Bangsbo J. Warm-up strategy and high-intensity endurance performance in trained cyclists. *Int J Sports Physiol Perform*. 2015;10:353-60.
11. Gil MH, Neiva HP, Sousa AC, Marques MC, Marinho DA. Current approaches on warming up for sports performance: A critical review. *Strength Cond J.* 2019;41:70-9.
12. Harris DJ, Macsween A, Atkinson G. Standards for ethics im sport and exercise science research: 2018 update. *Int J Sports Med*. 2018;38:1126-31.
13. Brzycki M. Strength testing: predicting a one-rep max from repetitions to fatigue. *J Phys Educ Recreat Dance.* 1993;64:88-90.
14. Jeffreys I. *The warm-up. Maximize performance and improve long-term athletic development.* Champaign, Human Kinetics; 2019.
15. Racinais S, Oksa J. Temperature and neuromuscular function. *Scand J Med Sci Sports.* 2010;20:1-18.
16. Sargeant AJ. Effect of muscle temperature on leg extension force and short-term power output in humans. *Eur J Appl Physiol Occup Physiol.* 1987;56:693-8.
17. Baskaran S, Seemathan P, Sadhasivam S. Effect of passive, active and combined warm up on the lower limb of healthy individuals. *Inter J Res Pharm Sci.* 2019;10:1785-8.
18. McGawley K, Spencer M, Olofsson A, Andersson E. Active, passive, and combined warm-ups among junior alpine skiers in -7°C. *Int J Sports Physiol Perform*. 2021;16:1140-7.
19. Kosuke T, Masahiro T, Masatoshi N, Fumiko T, Shumpei M. Effects of active and passive warm-ups on range of motion, strength, and muscle passive properties in ankle plantarflexor muscles. *J Strength Cond Res.* 2021;35:141-6.
20. Özcan M, Bicer M, Özdal M, Şan G. The effect of active and passive warm-up on individual and team sports athletes anaerobic power. *Biol Exerc.* 2018;14:51-9.
21. Ahsan M, Mohammad A. Effects of different warm-up techniques on dynamic balance and muscular strength on players: a study. *Eur J Phys Educ Sport Sci*. 2018;4:29-39.
22. da Costa JV, da Costa JV, Oliveira M, Pires GP. Efectos del entrenamiento pliométrico e isométrico en la fuerza explosiva de miembros superiores de atletas de balonmano. *Rev Cienc Act Fís UCM*. 2020;16:49-54.
23. González Y, Gálvez AY, Mendoza D. Comparación antropométrica, fuerza explosiva y agilidad en jugadoras jóvenes de baloncesto de Bogotá-Colombia. *Retos.* 2020;38:406-10.
24. Moreno CJ, Herrera IG. La fuerza explosiva y rápida como capacidades físicas determinantes en el entrenamiento de voleibol contemporáneo. *Rev Cub Med Dep Cul.* 2013;8:1-15.
25. Gogte K, Srivastav P, Balthillaya MG. Effect of passive, active and combined warm up on lower limb muscle performance and dynamic stability in recreational sports players. *J Clin Diagnostic Res.* 2017;11:5-8.