Chapter

Warming-Up for Resistance Training and Muscular Performance: A Narrative Review

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Abstract

Warming-up is an indispensable component of any type of training, aiming to prepare the body for the intensity required by the following exercises. The use of different types of warm-up seems to produce different results, mainly because of the effects on force production. However, the research is not clear and further research is needed. The present study aimed to analyze and discuss the main results of the literature regarding the effects of warm-up on force production, as well as to analyze those responses during resistance training and maximal strength assessments. Additionally, based on the outcomes, we intended to suggest some practical recommendations for sports-related professionals and researchers, providing essential knowledge for their intervention near the athletes, and also to contribute to the performance optimization during training and in the competition. For this, a search on four databases (Web of Science, Scopus, PubMed, and ScienceDirect) for original research published until November 2020 was performed, and then the outcomes were critically analyzed. The literature revealed that there is still little agreement on what should be the best warm-up to be used for strength performance and training. We, therefore, concluded that more research must be carried out and new approaches must be taken to clarify this issue.

Keywords: strength, performance, pre-exercise, warm-up, training control

1. Introduction

The warm-up is widely understood as a preparation practice to perform before any physical exercise. It is usually used by athletes, coaches, and general physical activity participants, to obtain an optimal physical and psychological state and to get kinetic and coordinative preparation in the prevention of injuries during the practice [1–4].

Based on previous studies, the main benefits of the warm-up were increased body temperature, decreased muscle and joint stiffness, [5] increased efficiency in the transmission of nerve impulses, [6] and, simultaneously, the increase in metabolic reactions, leading to the improvement of muscle power [7]. It may also lead to an increase in the dissociation of oxygen, hemoglobin, and myoglobin, causing vasodilation and, consequently, an increase in muscle blood flow [8].

These changes could be promoted by two basic types of warm-up, specifically, the active and passive warm-up [3, 9]. Hot water bags, short waves, hot baths, sauna, are some of the means used to complete a passive warm-up [3, 9]. This type of warm-up provides an increase in muscle and central temperature without energy expenditure, with the use of external heating [3, 9]. On the other hand, the active warm-up can be performed through the use of physical activity, for instance, walking, running, swimming, cycling, or any other specific exercises [3, 9, 10]. One of the main advantages of the active warm-up is its specificity, as it prepares the muscles that will be used during the activity and could benefit from the movement itself [3, 9].

Despite the positive influence of warm-up on sports performance, [9] there is still a lack of specific investigations about the variables that compose it, the optimal warm-up design as well as its effects on the force production and strength training performance [11, 12]. Any movement performed during physical activity requires the use of specific muscles to produce movement. The movement depends on muscle performance and therefore force production, either in maximal or submaximal efforts so that the exercise could be carried out successfully. The role of muscle strength performance is widely recognized in the scientific and sports context [9, 13]. Maximizing the strength and optimizing force production should be a priority to any person participating or willing to participate in sports performance or physical exercise. For this performance improvement, in physical activity and sport context, resistance training (strength training exercises where muscles exert a force against an external load) assumes an important role to develop individual capacities. Moreover, to improve the efficiency of resistance training and force production, the warm-up could be essential. It is important to understand the way that warm-ups can influence strength training and performance, to analyze the effects, and then to provide a useful strategy to apply in the real context. With this knowledge, professionals are able to design a warm-up that will optimize resistance training and thus, maximizing strength gains, force production, and resulting in improvements in physical exercise performance.

It is then important to understand the effect of warm-up in strength performance and this may be through the assessment of maximum dynamic strength (load at 1 repetition maximum: 1RM), isometric strength, or even through the rate of production of muscle strength [3, 10–12, 14]. Previous findings suggested that the warm-up procedure (for example, aerobic exercise, specific activity, and stretching) seems to influence the results of the 1RM assessment, as well as to improve the strength produced during the assessments [3, 12, 15]. Generally, it is recommended that the warm-up routine prior to a 1RM test includes general (aerobic) and specific (imitating target activity) exercises [16–18]. The general warm-up is usually completed using an aerobic activity of low to moderate intensity with the main purpose to increase the muscle temperature, which can be performed with different types of aerobic activity (for example, running or cycling) [3, 10, 12]. Stretching exercises can also be performed as part of a typical warm-up routine. Regarding the specific warm-up, it is recommended to perform it by including exercises that use the same or similar movements as the main activity at progressively higher intensities in an attempt to increase neuromuscular activation [2, 12]. In fact, there is suitable scientific evidence in the literature to support the implementation of only specific warm-ups before exercise, [19, 20] however, the effects of general warm-up on strength measurements are not clear yet.

In order to design an effective warm-up, several parameters and variables are associated with it, which seems to be extremely difficult to select an ideal type of warm-up for all sports. Then, it is necessary to understand what type of warm-up

is more appropriate to the variable that influences performance in all exercises, i.e. force production. Thus, our narrative review aimed to analyze and discuss the main results of the literature on the effects of warm-up on force production and strength, by analyzing responses during resistance training and assessments of maximum strength. The results determined in this study, aimed to elucidate sport-related professionals about the effects of warm-up and help them to design their training.

2. Methods

The current study intended to summarize the findings and evidence reported in the literature about the effect of warm-up protocols in force production, strength evaluation and resistance training. In order to identify relevant articles on this topic, an extensive bibliographic search was carried out. Of all the articles identified, only nine were chosen, which corresponded to the theme addressed here.

2.1 Search strategy

A search in the literature that studied different types of warm-up was conducted, where the focus was to understand the effects of warm-up in strength performance. Considering that active warm-up is the most commonly used by people engaged in sports and physical exercise and that is the most investigated, it was only included original articles that focused on the effects of active warm-up. Original research articles published between 2010 and 2020 were selected to identify studies in which warm-up and strength performance were reported. The search for scientific articles was performed in 4 databases (Web of Science, Scopus, PubMed and ScienceDirect) in which the keywords "warming-up", "resistance training" and "strength" with multiple combinations were used and with no restrictions of language.

2.2 Inclusion and exclusion procedures

To carry out this research, the studies had to respect inclusion criteria such as, being focused on active warm-up, being cross-sectional studies, focusing on measures of strength, being carried out by healthy individuals, aged 18 years or over. As exclusion criteria, all types of review (qualitative review, systematic review and meta-analysis) were excluded, the non-use of at least one active warm-up and studies with young participants (<18 years old). Articles that were not written in English were also excluded.

3. Results

The literature search found 163 relevant articles, of which 152 did not meet the defined inclusion criteria. These studies were excluded based on the focus on other physical activities rather than strength-related ones, such as running performance, anthropometric characteristics, or strength evaluation performed in participants of other chronological ages including children. Consequently, a total of 11 studies were considered for further analysis. These studies were published between 2009 and 2020. The studies focus on the results that different types of warm-ups may cause in resistance training (**Table 1**).

Authors	Objective	Sample	Warm-ups	Main outcomes
Ribeiro et al. [21]	Verify the effects of three specific warm-ups on squat and bench press resistance training.	14 males	3 protocols: • 40% of training load • 80% of training load • 40% and 80% of training load	The results showed that the strength outputs were optimized mainly by warm-up with 80% of the training load in the squat training and by the warm-up that brought the two loads together (40% and 80%) in the bench press training.
Krzysztofik and Wilk [22]	Determine the effects of plyometric push-ups as a conditioning activity on high-loaded bench press performance.	24 males	2 protocols: • conditioning activity • aerobic warm-up	The results demonstrated that plyometric push-ups lead to performance enhancement of the bench press exercise at 70%1RM.
Rodrigues et al. [23]	Investigate the acute effect of three different warm-up protocols on a maximal isokinetic strength test.	22 males	3 protocols: • general warm-up • stretching warm-up • specific warm-up	None of warm-ups were able to change the total work of maximal isokinetic strength.
Mina et al. [24]	Examine the influence of another form of variable resistance during a warm-up on subsequent free-weight 1RM back squat performance compared to free-weight resistance alone.	16 males	2 protocols: • free-weight resistance • chain-loaded resistance	The results are indicative of a potentiating effect of chain-loaded resistance in a warm-up.
Ribeiro and Romanzini [25]	Investigate the acute effect of different warm-up procedures on the repetition performance of a fatiguing resistance training protocol designed to induce metabolic stress.	15 males	4 protocols: • control • specific • aerobic • combined	No significant difference for the sum of repetitions or for fatigue index among conditions for the 3 exercises.
Abad et al. [26]	Investigate whether the combination of a general with a specific warm-up protocol would improve leg press 1RM values compared with a specific warm- up protocol.	13 males	2 protocols: • combination of a general with a specific warm-up • specific warm-up	These results suggest that a general with a specific warm-up protocol induced temperature-dependent neuromuscular adjustments that increased muscle force production capacity.

Authors	Objective	Sample	Warm-ups	Main outcomes
Chattong et al. [27]	Investigate the potentiating effects of different levels of external resistance during box jumps on vertical jump performance.	12 males	5 protocols: • Control • 5, 10, 15, or 20% of their body weight	Performing an active dynamic warm-up with or without a weighted vest produced significantly greater posttest vertical jump performance.
Sotiropoulos et al. [28]	Determine the effects of a specific warm-up using half-squats at low and moderate intensity on vertical jump performance and electromyographic activity of the thigh muscles.	26 males	2 protocols: • low intensity • moderate intensity	The use of a specific warm-up that includes half-squats performed explosively with low to moderate intensity, improves countermovement jump performance.
Barroso et al. [29]	Investigate the effect of different intensities and durations of general warm-up on 1RM performance.	16 males	5 protocols: • control • short duration and low intensity • long duration and low intensity • short duration and moderate-intensity • long duration and moderate-intensity	Long-duration low-intensity general warm-up seems to be appropriate to improve 1RM performance in strength-trained individuals
Resende et al. [30]	Analyze different types of warm-up on the physical performance of Paralympic powerlifting athletes.	12 males	3 protocols: • without warm-up • traditional warm-up • stretching warm-up	The different types of warm-up methods did not seem to provide significant differences in the force indicators in elite Paralympic powerlifting athletes.
Girard et al. [31]	Investigate the influence of two warm-up protocols on neural and contractile parameters of knee extensors	10 males	2 protocols: • running-based warm-up • strength-based warm-up	Running and strength-based warm-ups induce a similar increase in knee extensors force-generating capacity by improving muscle activation.

Table 1.
Main characteristics of studies.

4. Discussion

It has been evidenced that the warm-up brings positive effects to the subsequent physical exercise, so it is very important to study it and understand how it can be manipulated according to the specificity of exercise training and performance. The purpose of this investigation aimed to analyze and discuss the main results of the literature regarding the effects of warm-up on force production, as well as to

analyze those responses during resistance training and maximal strength assessments. The scarcity of research on warm-up protocols in resistance training and strength performance is notorious. Nevertheless, it is possible to verify that the results obtained in most studies are positive. The use of warm-up causes enhancement of performance when external loads are used, especially when the intensity is high. However, more research should be carried out on this topic.

The selected articles of this review tend to focus on the effects that warm-up produces on resistance training, namely the effects on strength performance. Due to the scarcity of articles about the addressed issue, it was difficult to compare the different types and approaches of warm-ups. Moreover, it was also noticed that exercises were not the same in different studies, which also difficult outcomes analysis.

In the study of Rodrigues and collaborators, [23] three different types of warm-up were compared: a general warm-up, a specific warm-up, and a warm-up through stretching, to understand whether it would influence maximal isokinetic training. The results reported that the three types of warm-up had no adverse effect or any type of improvement in acute muscle strength. However, it is important to highlight that the peak of concentric torque reported a lower value in the specific warm-up protocol when compared to the control group, which may mean that the use of a specific warm-up tends to reveal positive results when compared to the control group, which did not perform any type of warm-up.

The study by Ribeiro and Romanzini [25] aimed to compare the effects of three types of warm-ups on the performance of resistance training: a specific warm-up, an aerobic warm-up, and a combined warm-up of both, also using a control group. This study had the particularity of evaluating the performance using repetitions until failure, thus observing whether the conditions would affect resistance training. As in the abovementioned study, none of these conditions showed significant differences in resistance training, although no negative effects were observed after applying a warm-up. This study seems to suggest that the warm-up protocols used do not contribute to the development of strength.

Although the previous two studies have not found a significantly positive response in the strength assessment, the literature reported several benefits on the human body when considering the implementation of warm-up before resistance training [12]. In the study by Abad and his collaborators, [26] the aim was to understand if the implementation of a general warm-up before a specific warm-up would be beneficial when compared with a specific warm-up only. The tests were measured in the leg-press exercise, being evaluated by its 1RM. Two protocols were used in order to determine the effects of warm-up on training: combined warm-up (general with specific) and specific warm-up. The results of the combined warm-up were higher values in the force production, in comparison with the specific warm-up. Considering the positive results of the tests, a combined warm-up would have more benefits than a specific warm-up.

Barroso and his collaborators, [29] purposed to understand the best intensity to use in the general warm-up before the specific warm-up. Thus, four combined warm-up protocols were performed, with different intensities and durations, which were compared with each other and with a control group, which performed only a specific warm-up, with no general warm-up. These researchers found that a general warm-up followed by a specific warm-up would be more beneficial to increase the strength when compared to a specific warm-up that reported lower results. The authors also suggested that when performing the aerobic component of general warm-up, it should be long lasting with low intensity for better results.

On the other hand, the results of Krzysztofik and Wilk [22] did not corroborate with the studies of Abad and his collaborators [26] and Barroso and

his collaborators [29]. This study aimed to compare a specific warm-up (named conditioning activity) with a general warm-up, performed before a bench press exercise. In this study, the specific warm-up was performed with a different exercise (plyometric push-ups) from the training exercise (in this case, bench press). The researchers concluded that the use of a specific warm-up had significant results in the strength assessment compared to the general warm-up. The outcomes showed improvement in the bench press exercise performance, being incongruent with the previously mentioned results.

Otherwise, Ribeiro and colleagues, [21] aimed to understand the best intensity to use when only a specific warm-up was performed. This study verified if three types of warm-ups would have an effect on strength training, and its protocols would use three types of external loads in the warm-up exercise: 40% of the training load, 80% of the training load, and the combination of the 40% and 80% of the training load. Positive effects in force production were found when warming-up with higher loads (80% of the training load) before the squat exercise training. The same authors also reported that, when performing a warm-up with low loads and repetitions, there was no effect on strength training performance.

Similar to Ribeiro and colleagues, [21] Minas and collaborators [24] evaluated a specific warm-up in their study. These authors, although also used the squat exercise in their study, used two different warm-ups. A protocol with a chain-loaded (as external weight) and another where it would be used only with the weight of the body, without any help from external loads. The aim of this study was to perceive the effect of another form of variable resistance in a warm-up compared to a warm-up with only bodyweight. After applied the two defined protocols, it was concluded that using a chain-loaded weight as the body's external weight can enhance our results in the field of strength. Then, it is possible to notice that this study is in agreement with the previous one, although it cannot be directly compared. Both concluded that when using a warm-up with external loads to our body, the results tend to be better.

Sotiropoulos and his collaborators [28] carried out a study to determine the effects of a specific warm-up using low and moderate-intensity squats in the vertical jump. In his study, two warm-up protocols were performed using two different external loads (low and moderate), before performing the countermovement jump. Both protocols demonstrated to be effective when performed before the vertical jump, reporting significant results in the acute force production and the electromyographic activity, showing to be quite beneficial for the countermovement jump.

In the study of Chattong and his companions, [27] which aimed to investigate the potentiating effects of different levels of external resistance (weight vest) during box jumps in the vertical jump, five different warm-ups were assessed. The control condition was performed without any external load and then, the experimental warm-ups were performed with additional weight from 5% to 20% of bodyweight. In this study, the researchers concluded that no improvements in force production were found when increasing the load in the different warm-ups, not even any between using a vest or without it.

The study by Resende and his collaborators [30] aimed to analyze three different types of protocols, to understand their effect on the physical performance of paralympic powerlifting athletes. The protocols applied were: without warm-up, traditional warm-up and stretching warm-up. The results indicated by the researchers revealed that there were no significant differences when applying any of the protocols studied. Although the results did not show significant results, it is important to note that the participants were highly trained athletes and this might have triggered these results.

Gerard and his colleagues, [31] performed the following protocols: running-based warm-up and strength-based warm-up to investigate the influence of two warm-up protocols on the neural and contractile parameters of the knee extensors. It was revealed a significant shortening of time to contract, while the other twitch parameters did not change significantly. Thus, they concluded that both protocols can influence strength training and muscle contraction during training.

After analyzing these studies, there is still controversy around the issue of warming. All studies included in this narrative review are relatively recent, but a consensus has not yet been reached, neither what is the best type of warming up that will have the best results on force production and strength performance. Further investigations should be developed to provide a consensus and clarify the subject. For future studies, it would be interesting to explore this topic a little more. We suggest to study the effect of warm-up on strength training, exploring different types of intensities, in order to achieve more robust and concrete results. The same studies should not be based on a single exercise, but rather deepen the study on several exercises performed in a sequence. It is true that, in a real training context, no single exercise is performed. For example, most resistance training includes more than one exercise and for different muscular groups. It would also be interesting to verify if it will be necessary to warm-up before each exercise and specifically for each exercise, or if the first warm-up before training is enough to guaranty better results during the entire training.

5. Conclusion

With this narrative review, we could verify that there is a great lack of studies on the subject of warm-up for strength performance, resistance training performance, and force production. It was also possible to show that some authors did not report benefits after warm-up, however, others found quite significant results in their studies. These positive results were either after using only a specific warm-up or using a general warm-up followed by a specific warm-up. So, it is possible to determine that special attention on this topic is needed. Nevertheless, most of the studies tended to suggest that a warm-up should be performed before resistance training is performed. The increased strength outcomes seemed to be better when a higher load is used during warm-up, with few repetitions. Moreover, the use of a general warm-up showed to be beneficial in some specific assessments. Therefore it can also be a strategy to be applied and combined with the specific warm-up. Further investigations should be developed to better understand and determine the effects of warm-up, or even other studies using another type of exercise, so we can provide a more in-depth conclusion.

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