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# Current approaches on warming-up for sports performance: a critical review

Review Paper

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**Abstract**

Warm-up procedures have become relevant for coaches, researchers and sports professionals in recent years. Several studies have been conducted to verify the effects of different pre-activities, regarding differing volume, intensity, rest, and specificity, and the warm-up is now widely accepted as essential practice to improve performance. Research is now focusing on the effects of static and dynamic stretches, the post-activation potentiation phenomenon and the optimization of waiting periods with passive warm-up approaches. In this brief review we critically analyze the emerging methods and strategies of warm-up that have been investigated and used before competitive events.

Keywords*:* Competition; pre-exercise; heating; training; sports performance

**INTRODUCTION**

Before a competitive or training event, athletes usually engage in various activities to increase preparedness and optimize performance, usually refer to as warm-up (54). According to Swanson (83) the purpose of a warm-up is to prepare the athlete for the requirements of training and/or competition. It is believed that a well-designed warm-up causes physiological changes and helps the athlete to increase their mental focus on the next task, allowing them to optimize their performance (54, 62).

Warm-up techniques can be broadly classified into two major categories, passive or active (6). Passive warm-up involves raising muscle temperature (Tm) or core temperature (Tc) by some means (e.g. showers or baths, saunas, diathermy, heating pads). Active warm-up involves exercise and is likely to induce greater metabolic and cardiovascular changes than passive warm-up (e.g. jogging, calisthenics, cycling). An active warm-up, involving physical exertion, is the preferred and most commonly used method in almost all athletic events, with some studies reporting additional effects beyond increased temperature. Priming physical activities might stimulate buffering capacity, maintaining the acid-base balance of the body (3, 48) and perhaps increasing the baseline of oxygen uptake at the start of subsequent practice, which potentiates the aerobic system (9). Studies have also found increased motor neuron excitability (74) and reduced muscle stiffness (68), allowing easier and more efficient action. Nevertheless, passive strategies have recently been studied as a reliable alternative to active procedures, allowing the increased temperature obtained during warm-up to be maintained (41, 53, 90).

More than 80% of the published research has shown the positive effects of warm-up on physical performance (26), although the impact depends on the intensity and duration of the competition and on the time lag between the warm-up and the competitive event (61, 63, 97). Warm-up practices have been extensively studied over the last few decades (6, 62, 63). These practices in individual or team sports usually included a brief period of submaximal aerobic activity (e.g. submaximal run), followed by specific tasks and/or stretching (54, 96, 98). While the first is performed at low intensity, the subsequent specific exercise could be performed at higher intensity (e.g. race-pace) to prepare for a competitive event (56, 60). It may also include dynamic stretching and/or static stretching to reduce muscle stiffness and increase range of motion (42, 95), agility exercises and plyometrics to potentiate in force production (52, 59), as well as the use of thermal-specific clothing to increase or maintain temperature to optimize performance (1, 44). There is thus a wide range of warm-up procedures that can be combined and used by coaches and athletes, but further evidence from controlled studies is needed to demonstrate their efficiency (28).

Over the years, research has focused on different warm-up volumes, intensities, and tasks, but there are still many areas that need to be understood (7, 62, 91, 98). Further, there is a difference between the simulated conditions found in research and those that occur in a real context. New investigations have sought to fill this gap by trying to understand how other new procedures can be used as alternative and/or as complementary tasks to the conventional warm-up methods used by coaches and athletes (2, 73). New trends in research have therefore emerged, investigating the use of different warm-ups combined with several stretching strategies, tasks focused on post-activation potentiation (PAP), and various tools for passive warm-up that could be used to optimize the usual waiting period between warm-up and competition (2, 51, 55, 73). The present article therefore briefly reviews and highlights the newly emerging methods of active and passive warm-ups used before any competitive event to maximize performance. In brief, this review attempts to summarize and draw conclusions from the many studies that have investigated the mechanisms by which warm-up may affect performance, and changes in performance when static or active stretching, warm-up using PAP or external heating garments are used.

**STRETCHING DURING WARM-UP**

Static stretching is a common practice during physical activity and according to Knudson et al. (42), the use of stretching as a part of a warm-up routine may improve performance and decrease the risk of muscle injury. The goal of stretching during warm-up is to reduce muscle stiffness, and increase range of motion, thus reducing the incidence of activity-related injuries (29). Several researchers have recently shown that static stretching may inhibit sports performance, especially in explosive short-term efforts (5, 37, 45). The decrease in muscle strength and power when using static stretching may be associated with a change in the intramuscular viscoelastic properties, resulting in a decrease in the stiffness of the muscular-tendinous junctions (5). Even more than physiological and mechanical factors, current research has suggested that prolonged muscle stretching practices (more than 20s) could affect the efferent neural drive to the working muscles, as demonstrated by changes in electromyography signal amplitude, reducing muscle activation and resulting in the loss of force production (88).

Most studies investigating the loss of strength and power performance have evaluated intermittent stretching, that is several repetitions with rest intervals, which has led to negative changes in muscle contraction by affecting the force transmission between eccentric and concentric phases of movement, and thus the stretch-shortening cycle (50). According to Trajano et al. (89), intermittent stretching has been reported as more effective in reducing muscle stiffness compared to continuous stretching (no rest intervals), and this may therefore be associated with reduced muscle viscosity. However, Marchetti et al. (50) found a decrease in jump height performance after either static stretching with or without rest intervals between sets, despite the increased range of motion for both stretching routines. Since both continuous and intermittent stretching were performed for the same total duration, the authors suggested that the decreased performance could be caused by a similar total load (volume x intensity) from both protocols, that affected the elastic force transference during the stretch-shortening cycle. Despite only few studies have evaluated the effects of intervals between sets of stretches on performance (50, 89), it seems that high-speed, explosive or reactive efforts could be reduced with different static stretching strategies.

It is well known that one of the main factors influencing performance, especially in cyclic sports such as running or cycling, is efficiency, or how effective muscles are in using the available energy (36). This could depend on factors such as morphology, elastic elements and joint mechanics (10). Knowing that static stretching may improve the range of motion or even reduce muscle stiffness, possibly positively affecting running economy, recent studies have investigated the effects of static stretches on endurance performance. Wilson et al. (92) investigated the effects of 16 minutes of static stretching on 30 min running at 65% of maximum oxygen uptake ($VO_2max$) followed by 30 min at maximal intensity on a treadmill. The authors found 3% lower performance in the last 30 min ($p<0.05$) compared to a non-stretching warm-up. Accordingly, Lowery et al. (45) found that runners who performed six stretching exercises (3 repetitions of 30 seconds) for the lower limbs took more time to complete a 1.6 km ramp race than those who did not perform any stretches beforehand. When reducing the duration of stretching, however, the results seem to be the opposite. Takizawa, Yamaguchi and Shibata (84) investigated the effects of short duration static stretches (20 sec without repetitions) of the lower limbs after 15 minutes of general warm-up (running at 70% $VO_2$max) and found no significant differences in the running time to exhaustion, at 90% of $VO_2$max (817.9 ± 213.7 sec), compared with general warm-up only (819.3 ± 230.6 sec). In addition, no differences in $VO_2$max and blood lactate accumulation were found after the running performance test. The authors therefore suggested that endurance running performance is not affected by the inclusion of 20 sec static stretches in the warm-up exercise.

Variations in force production and performance might be due to changes in the length and stiffness of the musculotendinous unit, damage within the muscle itself that changes the contractile force capacity, reduced persistent inward current formation at the motoneurons and influencing central efferent drive, changes in electromechanical coupling and greater electromechanical delay due to the increased slack in the musculotendinous unit (for details please see studies 5, 17, 72). These could be considered the main mechanisms for explaining stretching induced changes on muscle force transmittal, causing impaired performances. However, by performing dynamic movements and specific activities after static stretching could reduce the possible negative effect on performance, reversing any undesirable muscular effect or associated neural effects (5, 43, 71). Marinho et al. (51) found that a 60 m sprint after static stretching warm-up resulted in better sprint performances than after dynamic stretching or without warming-up. The authors suggested that participants benefited both from the increased range of motion effects by static stretching, that might remain elevated for 30-120 minutes (57, 67) and from the muscle stimulation by the first 60 m sprint. Concordantly, ~~recently~~ Reid et al. (71) verified that the inclusion of dynamic stretching or dynamic activity after static stretching lightened some of the stretch-induced impairments and enhanced performance compared to baseline. Thus, it should be recommended that stretching should be followed by sport specific dynamic activities that would excite neuromuscular system wherever explosive or reactive forces are necessary or any decreases in performance would be important (5).

Evidence demonstrates that it only 10 minutes should be needed to restore the maximal values of isometric strength after a total of 5 minutes of static stretching (58). Often, the negative effects on strength are reported to subside within 10-15 minutes (4) but it can last up to 120 minutes following a stretch intervention (67). The different results suggest that longer periods of static stretching require a longer time to recovery to baseline levels (4, 5). Others suggest that the intensity of static stretching is a determinant of increased range of motion or even reduced performance (27, 38). Intensities equal to or higher than 100% of maximum tolerable intensity without stretching pain increased range of motion but decreased isometric muscle force (38). Some studies compared different stretching intensities by using the frequency of movement and found that high frequencies of movement (100beats/min) improved countermovement jumps, and lower frequencies (50beats/min) improved drop jumps (24). As dynamic stretching is usually performed using a motor-pattern identical to the following physical activity, some motor-learning and adaptation could be taking place and resulting in better performances (87). The measurement of dynamic stretching intensity by the number of movements is thus still quite limited. Athletes and coaches should be careful about the duration and intensity of static stretching protocol during warm-ups, and the inclusion of 20 sec of static stretching on each target muscle group, performed at lower than the maximum tolerable intensity without pain, is recommended (27, 38, 85).

Recent research suggested that dynamic stretches are safer and should be used instead of static stretching. Some studies have indicated that dynamic stretching can significantly improve power and agility (56), sprint performance (25), vertical and horizontal jumps (85), when compared with static stretching only. Dynamic stretching has been reported as a facilitator of power performance (19). Several reasons for this have been suggested, such as the resulting elevated muscle and body temperature, activation caused by voluntary contractions of the antagonist, stimulation of the nervous system, or a reduction in the inhibition of the antagonist muscles (35). The literature tends to show that shorter durations of dynamic stretching do not affect performance (5, 6, 35). In fact, positive effects were found in vertical jump height, electromyographic signal amplitude during vertical jump (increased neuromuscular response), and isokinetic muscle isometric leg strength when dynamic stretching was performed for 30 sec repetitions for each exercise, up to a total duration of 7 minutes (35, 78).

The literature reports that dynamic stretching resulted in more significant improvements than static stretching, or at least, no harmful effects were found (5). It could therefore be a safe practice to use during warm-up. Nevertheless, studies have suggested that dynamic stretching is not as effective as static stretching in increasing range of motion (18, 64). In some sports (e.g. gymnastics, some athletic disciplines) range of motion is essential to performance and therefore, coaches could choose static stretching (93). In this case, these practices should be followed by specific muscle activation activities. Behm and Chaouachi (5) pointed out that including static stretching during the warm-up followed by dynamic activity increased range of motion and decreased injury potential without subsequent negative effect on performance. In fact, Marinho et al. (51) recently found better performances in the second trial of 60 m sprints when including static stretches in warm-up, despite no differences were found between the static stretch or dynamic stretch warm-ups in the first 60 m of running performance. They suggested that the athletes benefitted both from the gains of a potentiation effect caused by the first sprint and from an increased muscular range of motion, whose effects might remain for 30 minutes after static stretches (57). This was not the only study to suggest that. Others found that static stretching had no significant effect on multiple sets of the back-squat exercise (32). Previously to these studies, Young (96) had already suggested that a low to moderate volume of static stretching performed between the general and specific components of the warm-up has no impact on subsequent performance.

Besides static and dynamic stretching, proprioceptive neuromuscular facilitation (PNF) is commonly used as a practice for increasing joint amplitude (4, 72). PNF incorporates static stretching and isometric contractions in a cyclical pattern no enhance joint range of motion, by contract relax technique and contract relax agonist contract technique (79). Despite the efficacy of PNF in increasing range of motion, this technique is rarely used during warm-up routines, because the need for a partner assistance, it may be uncomfortable or painful and muscle contractions performed at highly stretched muscle lengths can result in greater cytoskeletal muscle damage (4, 10). In their review, Behm, Blazevich, Kay and McHugh (4) estimated approximately a 4% reduction in performance after PNF stretching, with no studies presenting improved performances. Nevertheless, PNF mans an effective practice for increase range of motion and it impact on muscular performance should be further examined.

## WARM-UP USING POST-ACTIVATION POTENTIATION

PAP has been of great interest in recent years and has been demonstrated to have an ergogenic effect on performance (8, 30). PAP has been defined as an increase in force production after a maximum or near maximal muscle stimulation (37). Specifically, PAP augments a muscle's force-generating capacity (i.e. muscle twitch and low-frequency tetanic force) as a result of the previous contractile history of the muscle cells involved in the previous contraction (34). The main mechanisms responsible for this aid are still not clear, but studies have tended to attribute improvements to the increased phosphorylation of the myosin regulatory light chain, especially in type II muscle fibers (47, 86, 94). The actin-myosin interaction via calcium ions released from the sarcoplasmic reticulum and the myosin light chain kinase increase the rate of actin-myosin cross-bridging. This increased rate of cross-bridge formation allows a faster rate of force development (86, 94). Some research has also speculated about the elevation of excitation potentials across synaptic junctions at the spinal cord, the increase in the quantity of neurotransmitters released and their efficacy, resulting in the increased conduction of the nerve impulse to the muscle, and the quantity of recruited motor units (47, 86). It therefore seems that this method causes neuromuscular changes and improves type II muscle fiber activity, thus favoring performance in high-intensity and short-term activities, such as jumping, throwing and sprinting (21).

Different PAP effects have been described by using also different kind of exercises (34, 86). Research has reported that including depth jumping in the warm-up protocol increased both maximal strength (52), sprint performance (33) and vertical jump (33, 81). High external loads of strength exercise during warm-up also seemed to positively influence performance. A decrease of 3% in a 40 m sprint time was found 4 minutes after performing back squats at 85% of 1 repetition maximum (1RM) (70). Moreover, 10 and 30 m sprint performance was improved by between 2 and 3% 5 minutes after performing 10 repetitions of the half back squat exercise at 90% 1RM (13). Some controversial results have been found. For example, Kilduff et al. (40) found that one set of 3 repetitions of a squat exercise at 87% 1RM did not improve 15 m swimming performance of swimmers, compared to a traditional in-water warm-up. This perhaps demonstrates the need for the PAP stimulus to be specific to the activity performed.

It is difficult to use external loads in a real context venue, especially when using the higher-loads. Strategies using PAP stimulation without external loads are therefore continuously studied and are important for the sport community. Jumping is beginning to be recognized as a great stimulus during traditional warm-ups for short-term competitive events. For instance, Byrne, Kenny and O'Rourke (11) concluded that the addition of 3 depth jumps, which requires an athlete to drop from a predetermined height and perform a vertical jump immediately after ground contact, resulted in a 5% improvement of 20 m running compared to a traditional warm-up. To benefit from the effects of these kinds of practices, the ideal rest period for recovering between the jumping stimulus and main task should be between 5 and 10 minutes (15, 39) and should be take into account the intensity used (for instance, the jump depth and number of sets and repetitions) (39).

As well as the controversial results that were found (e.g. 49, 91), there were also inter-individual variability responses to PAP, and this should be of interest to coaches and athletes. The different methods used, including several types of exercises, intensities, volumes, and recoveries between stimulation and main task (86), could explain the different results found. The interaction between stimulation and fatigue has also recently been suggested as the main cause of an individual's improved or impaired performance. It seems important to determine not only the best exercise to promote physical adaptation, but also to know how much rest is needed in order to benefit from neuromuscular changes without physical impairment due to fatigue accumulation from previous stimulus. PAP should also be specific to the subsequent movement, and it depends on a subject's level and characteristics (76, 77). For instance, stronger individuals have greater type II fiber content, which has been related to a greater expression of PAP (76, 86) and possibly a more rapid recovery.

## WARMING-UP USING EXTERNAL HEATING GARMENTS

Several studies report significant losses in body temperature during the transition period between warm-up and main physical activity, causing a potential reduction in performance (44, 59, 61). On the other hand, some time is required between finishing an active warm-up and the beginning of a race, to allow restoration of the acid-base balance (7), restoration of phosphocreatine (20) and to benefit from muscle potentiation (41). Strength and conditioning coaches should be cautious about this recovery, however, so that performance will not be compromised. In this sense, several active and passive warm-up strategies have been developed in recent years to recover from active warm-up, but at the same time to extend its main effects, such as elevated body temperature. For example, during athletics or swimming events, athletes complete their warm-up and may then have to sit in a call-room for up to 45 minutes. Active exercise is not usually possible during that period, and passive temperature maintenance could be one method used to mitigate the reduction in body temperature (16). These passive strategies could involve the use of warm clothing, survival jackets and/or heating pads. Such strategies are easily applied to the desired muscle groups to maintain Tm (41) and are now being investigated as a potential mechanism for optimizing performance.

Tm increases rapidly in the first 3-5 minutes of active warm-up, reaches a threshold after 10-20 minutes of activity and falls exponentially within 15-30 minutes after the cessation of exercise (22, 59, 61). Some years ago, Sargeant (75) demonstrated that every 1°C reduction in Tm led to a 3% reduction in the muscle power of the lower extremities. Conversely, Racinais and Oksa (69) showed that an increase of 1°C in Tm can result in a 2-5% improvement in the performance of the subsequent exercise. Temperature-related mechanisms were always thought to be the main focus of warm-up practices, however, the temperature attained during warm-up is reduced immediately after ending exercise. Neiva et al. (61) found that it only took 20 minutes for the Tc to be at basal levels, which could promote a negative impact on swimming performance. Also, Mohr et al. (59) verified 1ºC reduction in Tc during the 15 minutes time break in a soccer match that coincided with a 2ºC drop in Tm and in a 2.5% reduction in sprint performance. Concordantly, Kilduff et al. (41) demonstrated that a decline in post-warm Tc was related to a decrease in the power of the lower body muscles (r = 0.71).

According to Russel et al. (73) passive temperature maintenance during the interval reduces the decline in Tc, leading to an improvement in peak power as well as repeated sprint capacity. The study conducted by Cook et al. (16) revealed a 65% increase in body temperature when active warm-up was performed with a survival jacket and was related to a 20m sprint performance improvement. Faulkner, Ferguso, Hodder and Havenith (23) demonstrated that the use of athletic pants with an integrated heating element can improve peak sprint power in cycling by ~10%. The use of thermal garments during the transition phase between warm-up and subsequent exercise thus seems to be of great importance in maintaining temperature, resulting in optimized sports performance.

**WARMING-UP USING FOAM ROLLING**

New warm-up practices are being developed by coaches and athletes to complement the usual warm-ups. That includes the foam rolling self-myofascial release. Foam rolling was originally thought to reduce the pain and stiffness resulting from muscular adhesions (65). The vasodilation response recorded after foam rolling, suggests that foam rolling could provide performance benefits and thus be used during a warm-up (65, 66). Some studies have shown that myofascial release can improve the flexibility of muscles, tendons, ligaments, and fascia by releasing tension in tight muscles or fascia (14, 31) while increasing blood flow and circulation to the soft tissues, which in turn improves flexibility and the range of motion (46). This is thought to improve overall performance, however, there is little research supporting this theory. These practices have become common in the last decade as a complementary method of massage and recovery (31). In fact, the reduced feeling of fatigue could possibly extend and optimize acute and chronic performance (31).

A warm-up routine consisting of both the usual warm-up and a self-myofascial release resulted in improvements of performance between 4-7% in vertical jump, standing long jump, agility test, sprint running, and maximal strength in bench press (66). Others found that foam rolling was effective to increase flexibility and the range of motion of the quadriceps and hamstrings without hampering muscle performance (46, 82). Foam rolling acutely increased range of motion immediately after implementation but did not enhance vertical jump height either alone or in combination with dynamic activities (80). It was suggested that short bouts of foam rolling (1 session for 30-120 seconds) prior to activity does not enhance or negatively affect muscle performance but may change the perception of fatigue (14). Those foam rolling interventions should be preceded by a dynamic warm-up focusing on the body parts where the foam rolling technique was applied.

Nevertheless, we should acknowledge for the contradictory results that also were shown. For instance, it was found that antagonist muscle activation may be negatively affected following agonist foam rolling, and harmful for performance (12). Despite the trend for increasing the short-term effects of the joint's range of motion without decreasing muscle performance, adding foam roaming techniques to other warm-up procedures seems not to result in better performances. It was therefore suggested that the use of foam rolling might be better suited for other times throughout the day rather than being part of the warm-up (80). This is a new area of research and studies are still limited by small sample sizes, and the varied methods and outcome measures used, which makes it difficult to develop a consensus on the optimal program for use (14, 65, 66).

**PRACTICAL APLICATIONS**

After a period in which dynamic stretches were considered a viable and secure method compared to static stretches, it is now believed that implementing static stretching as an integral part of warm-up could be beneficial to specific performances. The literature demonstrates that short duration stretches do not affect long-term efforts and are recommended rather than long duration stretches. Specific exercise (i.e. short-term high-intensity stimulation of the main muscles that will be used) after stretching seems to reduce any detrimental effect and should be performed before the main task. Warm-ups that include PAP were very popular for improving performance in explosive activities. The most important thing to remember when using PAP stimulation is that different individuals reach maximum potentiation at different times. The stimulus should be specific, and the subsequent recovery may last between 5 and 10 minutes. The balance between intensity and fatigue should be considered in order to optimize performance. Another concern in recent research on warming-up is the importance of maintaining the effects of increased temperature during the transition phase between warm-up and competition. It seems evident that maintaining body temperature during the post-warm rest period is vital in order to avoid decreases in subsequent performance, and, for example, thermal clothing should be used to minimize such performance losses. Some suggestions for the warm-up procedures analysed in the current study are presented in Table 1.

*****Please insert Table 1 near here*****

## CONCLUSIONS

Warm-up has assumed a leading role in sports-related investigations in recent years, despite some controversies. Some complementary practices have been included in warm-up by coaches and athletes and discussed by researchers regarding their effects on performance. When analysing the previous research, we found that some studies did not reveal whether the conditions assessed were randomized. Using randomized conditions can avoid learning effect of the performance variables and reduce some possible bias effect. A lack of information about whether the same warm-up procedure was used at the same time of the day could be a main limitation, since day-to-day biological variation could have an effect on other factors that could influence performance. This bias effect should be avoided in future research. Furthermore, several types of warm-ups, differing in volume, intensities, recoveries, tasks, have been investigated to date, but most did not use controlled conditions (for example no warm-up condition), making it difficult to compare the results and thus hindering the transfer of the findings to practice. Most studies also did not evaluate the effects of warm-up in specific environmental conditions, such as in a real competition context, with high standards of external validity. Future research should focus on the improvement of passive and active strategies after finishing warm-up so that athletes can benefit of all the positive effects of warm-up. Authors also need to provide more detailed information with practical applications for coaches and researchers. This, together with increased knowledge about the fatigue caused by warm-ups, and about recovery time may reduce the harmful effects of warm-up and maximize performance.

Collectively, the studies included in this review showed that short duration stretches can be used, followed by another specific muscle activation according to subsequent main activity (e.g. jumping exercises before sprint running). The current review showed that dynamic stretching seemed to cause more improvement than static stretching, and both depended on the duration and intensity of the exercise. External short duration maximal efforts in PAP stimulus, whether using external loads or not, and specific to the following activity, followed by few minutes of recovery, provide beneficial neuromuscular responses and improved performance in high-intensity and short-term efforts. Recent findings suggest a potential role for the inclusion of external passive heating (e.g. thermal garments) during the transition phase between warm-up and main exercise, in order to optimize subsequent performance. These recent trends could be useful tools for coaches and athletes trying to maximize performance but can also be used as training strategies to improve velocity and power sets.

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**TABLE CAPTIONS**

**Table 1 –** Suggestions on stretching, post-activation potentiation and external heating procedures that could be used during warm-up.

**Table 1 –** Suggestions on stretching, post-activation potentiation and external heating procedures that could be used during warm-up

| Procedures | Recommendations | Specific comments |
|---|---|---|
| Dynamic stretching | < 30s per repetition<br>< 7 min total duration | Do not compromise either ballistic or long efforts performance<br>Can be applied before, during or after the warm-up<br>High-frequency of movements |
| Static stretching | < 10s per repetition<br>< 30s per target muscle | Tolerable intensity without pain (the range of motion at pain onset)<br>Followed by post-activation potentiation exercises<br>Not recommended for explosive efforts (<10s duration) |
| Post-activation potentiation | Maximal short-term stimulus (< 30s)<br>Performed 1 - 10 min before main exercise<br>Examples:<br>> 80% 1RM (< 5reps);<br>Depth jumps (< 5reps);<br>Short sprint (< 60m). | Main muscle groups used in the following activity<br>Avoid fatiguing effects (individualize short-term stimulation and rest) |
| External heating garments | Warm clothing<br>Survival jacket<br>For more than 20 min of waiting:<br>Heated garments at 40 - 43°C | Used after warm-up (waiting period before main event)<br>Can be combined with exercise during the waiting period |

1RM: 1 repetition maximum with external loads; reps: repetitions; < : less than; > : higher than.


ACCEPTED