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REVIEW ARTICLE

Building functional warm-up routines in basketball: a narrative review of literature

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Abstract

Warming up is a crucial preparatory activity used in training sessions and games. Therefore, the aim of this investigation is to examine the construction of functional basketball warm-up routines through a narrative literature review. Four electronic databases were consulted (MEDLINE, Google Scholar, Scielo and LILACS), where 47 articles were selected that discussed warm-up routines in basketball and team sports, as well as 09 textbooks in the field of sports training and physiology of the exercise. A well-designed warm-up promotes optimization in performance and prevents the appearance of injuries. However, there are multiple choices for building warm-up routines. Thus, the structuring of a warm-up should take into account the basic methodological aspects for them to be effective, such as: duration, intensity, adopted exercises, sequence of tasks, use of additional equipment, number of routines and recovery interval. Also, in basketball, the critical times to implement warm-ups are training sessions, game days, in-game re-warm-up, and half-time re-warm-up. Each of these points requires a distinct didactic-pedagogical approach in warm-up procedures. In this way, with the acquisition of a broader view of each component involved in this process, it becomes feasible to solve these issues. Finally, it is imperative that basketball physical trainers are able to masterfully solve the practical problems of warm-up, for more assertive decision-making in relation to routines that incorporate superior results in performance and reduction of injuries.

Keywords: Basketball, sports training, team sports, warm-up.

Introduction

Basketball is a team sport of territorial invasion. Its intermittent motor actions maneuver a wide variety of movements with intensities ranging from moderate to high, within a court with reduced dimensions and an environment of continuous instability. In a game, players move quickly using agility and muscle power to effectively face their opponents and score in their favor (Pociūnas et al., 2018; Vretaros, 2021a).

Quality athletic performance is sought during the competitive season. In view of this, the goal of physical preparation programs should be to gradually increase the functional potential of biomotor capacities, preparing athletes to tolerate future efforts of great magnitude. At the same time, these studies are aimed at reducing the appearance of injuries (Boyle, 2015; Weldon et al., 2021; Vretaros, 2021a).

The real guarantee of sports physical training for any sport modality is the fact that it serves as a basic structure so that the technical-tactical skills, organic and psychic demands, respond with excellence in the face of the residual accumulation of fatigue (Bompa & Haff, 2012; Towlson et al., 2013; Santos et al., 2020). As a matter of fact, the fatigue that affects basketball players, interfering with their performance, is central (affecting the neural impulse regulation pathway originating from the central nervous system), peripheral (affecting metabolic and neuromuscular components), visible (decrease evident in the ability to produce work) and

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hidden (compensatory loss of movement economy without reduction in work capacity) (Platonov, 2008; Powers & Howley 2014; Vretaros, 2021b). Therefore, a redoubled care about severe fatigue is indisputable, because it is related to reduced levels in the performance capacity of athletes (Bompa & Haff, 2012).

Training loads and competitions are arranged in a structured periodization model. Periodization systematically orders the stages of the process of acquiring physical and sporting form, configuring the equalization of operational problems that arise in sessions, microcycles, mesocycles, macrocycles and multiannual plans (Weineck, 2005; Platonov, 2008).

A training session is the smallest organizational unit of periodization. It is built in three interconnected parts. The first part is called preparatory, where the organic-biological bases are created through warm-up, seeking efficiency in the central activities of the main part of the session. The second part is called the main one and aims at methodological solutions in the biomotor capabilities to be trained. Finally, we have the final part (cooling down), with the physiological recovery of the loads imposed (Weineck, 2005; Issurin, 2008; Gomes, 2009).

Warming up is a relevant integrating component in basketball players' preparation moments, both during training sessions and matches (Weineck, 2005; Fradkin et al., 2010; Alberti et al., 2014). Warm-ups are pedagogical strategies implemented before a specific load, in order to establish an ideal state of psychophysical readiness (Weineck, 2005). Warming up routines preceding training sessions and games are common practices well accepted by physical trainers (Bishop, 2003a; Weineck, 2005).

Determining classification is made in the warm-up protocols, dividing them into passive or active. Passive warm-ups raise the body temperature through external means. In parallel, active warm-ups depend on physical exercises to raise core and muscle temperature (Bishop, 2003a; Bishop, 2003b; Weineck, 2005; McGowan et al., 2015; Hammami et al., 2016). In this research, we will focus on discussing active warm-up in greater depth.

A detail in the construction of warm-up routines is that there is attention to the needs of athletes and the respective modality (Jeffreys, 2006). The importance of warm-up lies in the fact that it provides the right conditions for athletes to demonstrate their full potential in training sessions and, especially, in competitions (Gomes, 2009; Berdejo-del-Fresno, 2011). The second reason to use warm-up routines is to stimulate the adaptive mechanism to protect the muscle against the risk of injury. A warm muscle will require a greater amount of stretch and force to injure it (Woods et al., 2007).

Absence or insufficient heating can lead to cardiac problems, such as the risk of myocardial infarction in the face of sudden and intense effort. The likelihood of muscle injuries without warm-up is a consequence of incorrect kinetic preparation and intra and intermuscular coordination. In this sense, it is noted that warm-up is considered the fundamental mandatory ingredient in the training process (Platonov, 2008; McArdle et al., 2011; Racinais et al., 2017; Gonçalves, 2021).

In general, the four primary objectives of warm-up are to optimize performance, reinforce the necessary technical skills, emotional preparation and prevent musculoskeletal injuries. Optimization in performance is due to the increase in body temperature, which contributes to neuromuscular function and cardiovascular gas exchange. Technical skills are reinforced by preparatory exercises with specific movement patterns. Emotional adjustment is consolidated by levels of psychological concentration. Injuries are prevented with warm-up because multicomponent exercises activate proprioception, tissue elasticity, decrease muscle viscosity, and stimulate strength and explosive power (Issurin, 2008; Platonov, 2008; Galazoulas et al., 2012; Gaetano & Gaetano, 2017 ; Räisänen et al., 2021).

The benefits of warm-up in the following activities are numerous, among them are mentioned: increased core and muscle temperature, faster muscle contraction, economy of movement, high oxygen delivery from hemoglobin to the muscles, muscle metabolism and recruitment of motor units facilitated, increased blood flow in arteries, kinetic acceleration in oxygen uptake, better blood pressure response, post-activation potentiation (PAP) and, post-activation performance enhancement (PAPE) (Weineck, 2005; Zois et al., 2011; McArdle et al., 2011; Ribeiro et al., 2014; Vretaros, 2021b).

In the composition of the warm-up, it is essential to organize the duration, intensity, exercises adopted, sequence of tasks, use of additional equipment, number of routines and recovery interval. These seven basic methodological aspects, when well modulated, consolidate a sustainable warm-up routine to optimize performance and, simultaneously, reduce the risk of

injury (Bishop, 2003b; Jeffreys, 2006; Woods et al., 2007; Gomes, 2009; Berdejo-del- Fresno, 2011; Zois et al., 2011; Taylor et al., 2013; Towlson et al., 2013; Hammami et al., 2016; Racinais et al., 2017; Russell et al., 2018; Eken, 2021; Silva et al., 2022).

In professional practice, many coaches build their warm-up routines through trial and error, experience gained over time, and empirical observations from elite teams (Fradkin et al., 2010; Silva et al., 2020). However, it is necessary to have more solid notions with scientific basis and ecological validity when building a warm-up protocol for basketball. So, to elucidate this question, this research aims to examine the construction of functional warm-up routines in basketball through a narrative literature review.

Method

The methodological design of this manuscript was based on a narrative literature review (Echer et al., 2001; Grant et al., 2009; Gaetano & Gaetano, 2017). In this named model of narrative review, the theme in question must be explicit and argued based on the complexity of scientific theory (Gaetano & Gaetano, 2017). The questioned research problem gathers and synthesizes knowledge from studies on the delimited theme, to seek knowledge innovation, reformulate concepts, verify similarities and notice discrepant differences (Echer et al., 2001). Through a careful description and analysis of the available evidence, the final product of the research will result in effective information to be used as a guiding element for field practice or future research (Sousa et al., 2017).

Four electronic databases were references for queries (MEDLINE, Google Scholar, Scielo, and LILACS) in Portuguese, English and/or Spanish, intending to find texts that commented on the theme of warm-up in sports preparation, physiology of warm-up, methodological aspects of warm-up, functional warm-up routines in basketball, and warm-up in team sports. The Boolean search used the respective key terms: "aquecimento", "warm-up", "calentamiento", "aquecimento AND\OR preparação esportiva", "warm-up AND\OR sports preparation", "calentamiento AND\OR preparación deportiva", "aquecimento AND\OR basquetebol", "warm-up AND\OR basketball", "calentamiento AND\OR baloncesto", "aquecimento AND\OR respostas fisiológicas", "warm-up AND\OR physiological responses", "calentamiento AND\OR respuestas fisiológicas", aquecimento AND\OR metodologia", "warm-up AND\OR methodology", "calentamiento AND\OR metodología", "aquecimento AND\OR rotinas", "warm-up AND\OR routines", "calentamiento AND\OR rutinas", "aquecimento AND\OR esportes coletivos", "warm-up AND\OR team sports", "calentamiento AND\OR deportes colectivos", "aquecimento AND\OR sessões de treinamento", "warm-up AND\OR training sessions", "calentamiento AND\OR sesiones de entrenamiento", "aquecimento AND\OR jogos", "warm-up AND\OR games", "calentamiento AND\OR juegos", "reaquecimento AND\OR jogos", "re-warm-up AND\OR games", "re-calentamiento AND\OR juegos", "reaquecimento AND\OR basquetebol", "re-warm-up AND\OR basketball", "re-calentamiento AND\OR baloncesto".

The articles found underwent a screening based on inclusion and exclusion criteria, so that the object of study of this investigation appears with adequate academic robustness. To define these criteria, there was a pre-selection through the title of the article, reading the abstract and reading the full text. In the inclusion criteria of the texts, the following were chosen: 1)- full texts addressing warm-up in competitive sports, 2)- studies that discussed warm-up and its importance in sports, 3)- research that commented on the physiological responses of warm-up, 4)- investigations discussing methodological aspects of warm-up, 5)- articles presenting warm-up routines in basketball, 6)- studies containing warm-up routines in team sports, 7)- research that reported on re-warm-up strategies in games, 8)- approaches warm-up in training sessions and, 9)- warm-up routines for injury prevention. Exclusion criteria suppressed incomplete texts, duplicates, and articles on warm-up in individual sports.

The final manuscript consisted of 47 scientific texts published between 2003 and 2023, 07 textbooks in the field of sports training theory, 02 textbooks in the field of exercise physiology, 01 master's thesis in motor science, 01 website organizational and, 03 studies about the methodology of scientific research.

Physiological Aspects of Warm-Up

The physiology of warm-up implies understanding the organic-biological responses triggered in a given protocol and/or routine. Organic changes from the resting state to the awakening of different functional systems are part of a well-conducted warm-up process (Weineck, 2005; Gomes, 2009). These responses vary according to the dose of exercises and their intensity during the warm-up. In general, the effects of warming

up may be due to temperature elevation (increase in nerve impulse conduction, decrease in muscle and joint resistance, greater oxygen availability, activation of metabolic reactions and thermoregulatory stress) and also a result of muscle activity (increased blood flow, increased oxygen consumption, neuromuscular activation, mental alertness, PAP and PAPE) (Bishop, 2003a; McGowan et al., 2015; Zagatto et al., 2022b).

Basically, warm-ups that precede training and games fall into two categories: active and passive. Active warm-ups mobilize large muscle masses, thereby raising core and muscle temperature. On the other hand, in passive warm-ups, body temperature is increased by external means, such as hot showers, saunas, hot tubs, thermal clothing, among other available resources. Currently, most of the warm-ups used are active and, on rare specific occasions, passive warm-up is handled. It appears that passive warming is seen as a complementary measure to active warming. In addition, research has reported that active warm-ups are superior to passive warm-ups in producing the ergogenic effect to improve athletic performance in subsequent tasks (Bishop, 2003a; Bishop, 2003b; Weineck, 2005; McGowan et al., 2015; Hammami et al. al., 2016).

When the warm-up is boosted, the internal temperature rises. A few minutes of active warm-up cause an increase in temperature that reaches values around 38.5°C to 39.0°C. This represents the optimal temperature to meet the biochemical and neural reactions necessary for motor work (Weineck, 2005). The increase in temperature is proportional to the rate of work performed (Bishop, 2003a). A 1°C rise in muscle temperature leads to a 2% to 5% improvement in performance (McGowan et al., 2015). In this way, the heat generated by warm-up boosts blood flow, dilating capillaries and providing enough oxygen for active tissues, as well as substrates that serve as fuel (Weineck, 2005).

Muscle temperature rises faster than core temperature. It is postulated that an increase of 2°C to 3°C in muscle temperature may favor the speed of its contraction (Racinais et al., 2017). Since, during warm-up procedures, the increase in muscle temperature is of paramount importance when compared to core temperature. It is stated that muscle temperature is considered the primary source of heat for those activities that will be performed next (Platonov, 2008; Alberti et al., 2014).

From the biochemical point of view, the effects of the increase in body temperature (core and muscle) with warm-up positively impact aerobic (oxidative phosphorylation), anaerobic (phosphocreatine, glycolysis and gluconeogenesis) metabolism and glycogen availability. Also, the neural pathway becomes more efficient in transmitting nerve impulse velocity. Such an observation causes a muscle contraction with faster activation and an increase in the rate of force development (Bishop, 2003a; McGowan et al., 2015; Gaetano & Gaetano, 2017).

Improvement in sensory feedback from proprioceptors, coordination of movements, production of joint synovial fluid and tissue elasticity are physiological consequences of warming up that can serve as elements of injury prophylaxis (Weineck, 2005).

Intrinsic and extrinsic factors affect the quality of warm-up. Three intrinsic factors stand out: age, training status and mental readiness. Players with more advanced age and great training experience need additional care during warm-up, as their muscles decrease tissue elasticity capacity. In young athletes, the warm-up may be shorter and more intense, as they are in their best organic and musculoskeletal conditions. Physical fitness is an intrinsic factor. Athletes with low physical conditioning can fatigue during warm-up and, therefore, affect subsequent tasks. Another intrinsic factor is mental readiness, showing that the state of psychic motivation can excite or inhibit the success of the warm-up. Players with high motivation are indicated a more extensive warm-up and with reasonable intensity. However, in athletes with low motivation, the intensity should be higher. In terms of extrinsic factors, the literature points out time of day, particularities of the modality, and weather conditions. The time of day is related to the circadian rhythm, showing that during the advance of the day the organism would be more predisposed when compared to the morning period. The sport modality factor results in organizing warm-up exercises according to the functional needs of the sport in vogue. Warm climatic conditions facilitate warming up, which can reduce the total duration time. On the other hand, in cold climates, the duration of warm-up should be prolonged (Weineck, 2005; Gomes, 2009; Silva et al., 2022).

Two neurophysiological phenomena can manifest shortly after warm-up routines, amplifying the ability to produce muscle power. They are: PAP and PAPE. PAP arises in an involuntary acute manner and is the result of a warm-up performed with maximum loads or the combination of maximum loads with explosive exercises

(complex method) (McGowan et al., 2015; Vretaros, 2021b; Silva et al., 2022; Zagatto et al., 2022b). Three elements govern the efficient functioning of the PAP: regulation of the phosphorylation of myosin light chain that increase the sensitivity of the calcium pump in the sarcoplasmic reticulum, the Hoffmann reflex that is related to pre and post synaptic neural factors, and the decrease of the angle of pennation allowing mechanical advantage in driving force to the tendon (Vretaros, 2021b). PAPE is seen as a chronic phenomenon, a residual effect of PAP. This neurophysiological response is also derived from warm-ups with maximum loads or explosive activities. The mechanism responsible for PAPE comes from the increase in muscle temperature, myofibrillar water retention and neuromuscular activation (Vretaros, 2021b). There is a strong dependence of the PAP and PAPE responses on the athlete's training experience, duration of the interval between the end of the warm-up and the tasks, level of fatigue, and the intensity of the load in the warm-up (McGowan et al., 2015; Vretaros, 2021b; Zagatto et al., 2022b).

Studies report the construction of warm-ups that aim to stimulate the ergogenic effects of PAP and PAPE in basketball. In the first research, with professional basketball players, two explosive warm-up routines and their PAP effects on the repeated sprint test were compared. The first routine consisted of five drop jumps at intervals of four minutes. In the second routine, the athletes performed three drop jumps with an interval of thirty seconds. The height of the boxes were 90-cm and 110-cm. In terms of results, both interventions improved performance in the repeated sprint test (Zagatto et al., 2022a). The second investigation with formative players compared the effect of drop jumping (explosive strength) or heavy sledging (maximum strength) on the production of the PAPE phenomenon in the repeated sprint test. It was proven that the drop jump promoted a positive response in the repeated sprint test, while the heavy sled had no potentiating effect (Zagatto et al., 2022b).

Methodological Aspects of the Warm-Up

The methodological aspects of active warm-up concern the structuring of the protocol: duration, intensity, exercises adopted, sequence of tasks, use of additional equipment, number of routines and recovery interval (Bishop, 2003a; Bishop, 2003b; Weineck, 2005; Jeffreys, 2006; Issurin, 2008; Berdejo-del-Fresno, 2011; Silva et al., 2020; Silva et al., 2022).

The ***duration*** of the warm-up fluctuates according to the number of exercises in the routine. Very prolonged duration times can impair performance in the main activities, as fatigue will be present. Short-term warm-ups may not be sufficient for a satisfactory increase in muscle temperature and activation of major muscle groups. Adding to this, in the elaboration of the warm-up, its duration time is directly related to the intensity. With moderate to high intensities, the duration can be a little longer. However, the use of high intensities for maximums makes long-term warm-ups unfeasible. In numerical terms, a typical warm-up period ranges from 15 to 40 minutes (Bishop, 2003b; Jeffreys, 2006; Gomes, 2009; Zois et al., 2011; Towlson et al., 2013; Racinais et al., 2017; Russell et al., 2018).

The ***intensity*** of the warm-up protocols should not be too high or too low. Very high intensities induce fatigue, causing a reduction in the availability of bioenergetic fuel to perform activities. In contrast, very low intensities are insufficient for adequate preparation of the locomotor system (Bishop, 2003b; Weineck, 2005). It is recommended that the intensity of the warm-up considers the level of physical conditioning of the athletes, in order not to exceed the limit of organic tolerance (Woods et al., 2007). In team sports, it is recommended that short warm-ups with effort intensities above the anaerobic threshold are more favorable when compared with lower thresholds (McGowan et al., 2015; Pociūnas et al., 2018). In Turkish basketball players, three warm-up intensities and their acute effects on maximal strength through the squat exercise (1RM squat) were compared. The first warm-up consisted of 5-minute jogging at an intensity of 30%-40% of maximum heart rate. In the second warm-up, the players performed jogging for 5-minutes and a series of 10 repetitions in the squat with a load of 40% of 1RM. In the third warm-up protocol, 5 minutes of jogging followed by a series of 10 repetitions of the squat exercise with a load equivalent to 80% of the 1RM. The warm-up routine with an intensity of 80% of 1RM was superior to the others in the performance of the 1RM test in the squat (9.4 kg, 8.5% in relation to the first protocol and 5.5 kg, 5.2% in relation to the second protocol, respectively) (Eken, 2021).

Exercises adopted in warm-ups have a general or specific character, as well as their activities are classified as continuous or intermittent, standardized or non-standardized, open skills or closed skills, and group or individual. General warm-ups stimulate large muscle groups with the function of raising the temperature of

the human body in multifaceted activities. In specific warm-ups, the aim is to activate muscles that participate in the main motor actions of the modality. Typically, general warm-up exercises are performed before specific warm-up exercises in a given routine. Continuous warm-up activities are cyclical in nature, like non-stop running. Intermittent activities, on the other hand, have an acyclic disposition with short or moderate intervals and task variations. The standardized warm-ups follow a logic of usual exercises in a pre-established order. In the case of non-standard warm-ups, the exercises are tailored to the needs of the main part of the training session. Open skills in warm-ups require anticipation of decision-making, along with high positive transfer of movements. Closed abilities are pre-planned moves. Group warm-ups integrate several athletes and, in individual warm-ups, players work individually (Bishop, 2003b; Weineck, 2005; Gabbett et al., 2008; Issurin, 2008; Gomes, 2009; Berdejo-del-Fresno, 2011).

The ***sequence of tasks*** covers the rational and logical ordering of exercises at the beginning, middle and end of the warm-up (Silva et al., 2020). The guiding concept is to perform less intense activities in the beginning and middle, concluding with more intensive activities in the final part of the warm-up (Fradkin et al., 2010; Zois et al., 2011; Russell et al., 2018; Silva et al., 2022).

The ***use of additional equipment*** is a coach's prerogative, given that most warm-ups can be performed without the use of material (Herman et al., 2012). Depending on the type of equipment you are looking for, there will be a need for appropriate logistics and sufficient physical space (Taylor et al., 2013; Hammami et al., 2016).

The ***number of warm-up routines*** is considered an important factor if we reflect on the principle of variability, to avoid the effects of monotony (Vretaros, 2021a). That said, it would be interesting for the physical trainer to have a collection of three to five warm-up routines with a wide range of exercises.

In terms of ***recovery interval,*** we are dealing with the time between the end of the warm-up and the subsequent activity. Again, the ratio of the bioenergetic fuel that needs to be replenished and the risk of fatigue if the interval is too short comes into play. Thus, recuperative intervals must be considered not to be relatively brief, interfering with the ability to restore adenosine triphosphate resynthesis. At the same time, they do not require a long period, so that the physiological benefits provided are not lost. The maximum acceptable time to avoid losing the biological advantages of warming up would be situated in 10-minutes (Bishop, 2003b; Weineck, 2005; Gomes, 2009; Berdejo-del-Fresno, 2011; Racinais et al., 2017; Silva et al., 2022). Some experts argue that passive warming up could be implemented in this interval to try to maintain body temperature (McGowan et al., 2015; Racinais et al., 2017). In college basketball, the acute effect of three transition times (3-minutes, 10-minutes, and 17-minutes) between warm-up and explosive activities was investigated. It was found that the 3-minute interval exhibited better performance in the explosive tasks of intermittent running and vertical jumps (Silva et al., 2022).

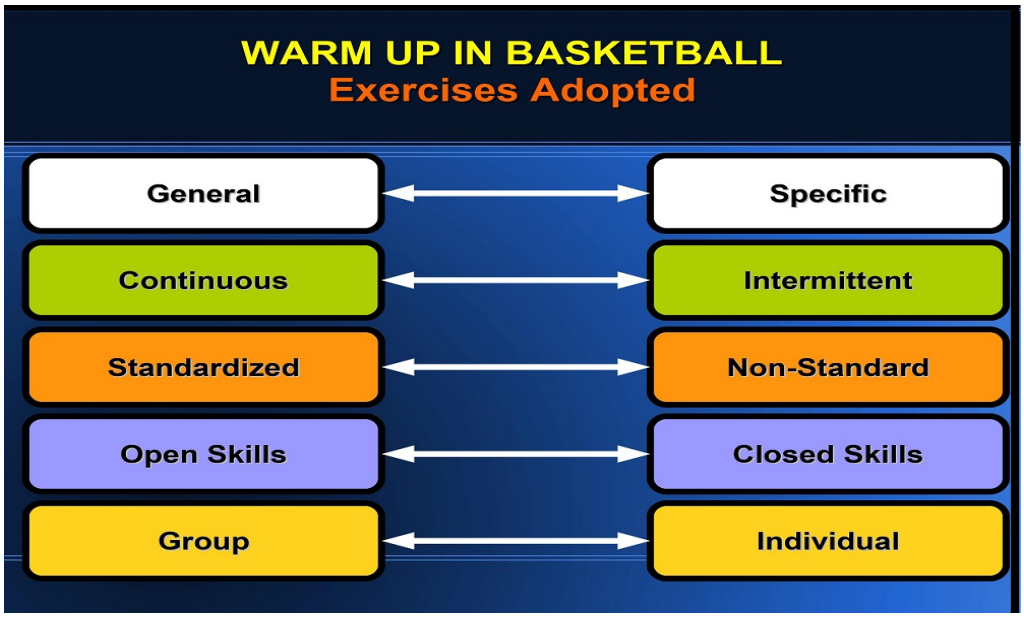

Figure 1. Characteristics of exercises adopted in warm-up routines.

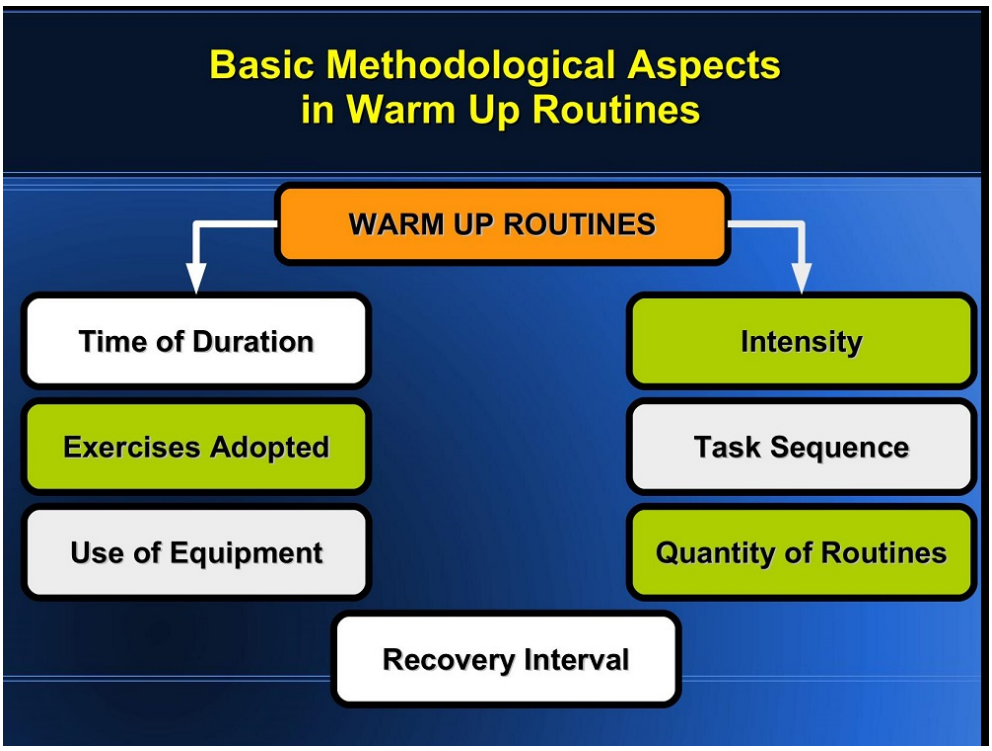

Figure 2. Seven basic methodological aspects of warm-up routines.

A multicomponent warm-up during training sessions and competitions, emphasizing the neuromuscular aspects, manages to improve strength, power, proprioception, agility, flexibility, movement technique, stabilization of joint segments and develop protective reflexes in activities that require rapid recovery of dynamic balance (Herman et al., 2012; Bizzini et al., 2013; Brunner et al., 2019; Owoeye et al., 2020; Stojanović et al., 2022). The FIFA 11+ multicomponent warm-up protocol was performed on formative basketball players for nine months, showing a reduction in the incidence of injuries when compared to the control group (0.95 per 1000 athlete-exposure hours versus 2.16 per 1000 athlete-exposure hours, respectively) (Longo et al., 2012).

With this type of warm-up, the nerve impulse transmission speed is increased and, with that, we have a better reaction time in explosive movements that involve turns, rotations and falls (Woods et al., 2007). Multicomponent warm-up programs focus on reducing noncontact injuries (Woods et al., 2007; Herman et al., 2012; Bizzini et al., 2013; Owoeye et al., 2020; Vretaros, 2021a). In the view of Issurin (2008), a certain percentage of injuries are caused by insufficient or poorly designed warm-up.

In the construction of warm-up routines, each specialist has suggested different methodological approaches or models. Some of these approaches are more traditional, others are more contemporary. In team sports, traditional warm-up uses cardiovascular activation exercises, followed by stretching and, finally, with specific movement patterns (Taylor et al., 2013). Also, we have modern strategies, with two-phase warm-up: closed skills and open skills (Gabbett et al., 2008; Silva et al., 2020). A variant comprising four sequential phases: raise, activation, mobilize and potentiate (Jeffreys, 2006; Racinais et al., 2017). Another concrete possibility is the execution of a hybrid warm-up, whose content would have myofascial self-release exercises, mobility, neuromuscular activation and explosive activities (Boyle, 2015; Boyle, 2018). Berdejo-del-Fresno's (2011) warm-up proposal for basketball includes two parts: general (proprioception, mobility, aerobic exercise, static stretching, dynamic stretching) and specific (reduced games, free shooting in the basket and layups). Finally, there is also the prospect of using the FIFA 11+ warm-up in basketball, which is built in three parts: temperature rise, prophylactic activities and specific tasks (Longo et al., 2012).

Regardless of the routine presented by the authors, the exercises of the warm-up protocols must be adjusted with the biological maturation of the athletes, competitive category, physical fitness of the team, time of day and environmental climate (Berdejo-del-Fresno, 2011; Silva et al., 2018). Table 1 presents six functional warm-up routines that can be implemented in

basketball.

Warm-ups, when well designed, take prudence and progressivity into account. Prudence concerns the selection of exercises, total duration, competitive category of players, level of physical fitness, state of motivation and weather conditions. In the issue of progressiveness, the intensity of tasks is dealt with, starting from activities with low and moderate intensities in the beginning to the middle of the warm-up, to explosive high-intensity activities in the final stretch of the same (Weineck, 2005; Issurin, 2008; Fradkin et al., 2010; Zois et al., 2011; Russell et al., 2018; Silva et al., 2022).

Table 1

Summary of six functional basketball warm-up routines.

Study	Type of Warm Up	Characteristics
(Adapted from Gabbett et al., 2008; Silva et al., 2020)	Two-phase warm up	**Closed Skills:** Static stretching, dynamic stretching, aerobic running, multidirectional sprints, skipping, and plyometrics **Open Skills:** Specific unopposed moves, reduced games, unopposed shooting, and opposed shooting
(Taylor et al., 2013)	Three-phase warm up	**Cardiovascular Activation:** Cardiovascular activation exercises aimed at raising core and muscle temperature **Mobility:** Dynamic stretching exercises **Specific Tasks:** Exercises reproducing modality-specific movement patterns
(Adapted from Jeffreys 2006; Racinais et al., 2017; Silva et al., 2018)	Four-phase warm up	**Raise:** Exercises to raise core and muscle temperature with dynamic movements **Activation:** Exercises to activate the main muscle groups responsible for generating more efficient movements (for example, body core, glutes, scapulae, etc.) and exercises to prevent injuries **Mobilize:** Static stretching and dynamic stretching exercises **Potentiate:** Exercises that stimulate the neurophysiological phenomena of PAP and PAPE
(Adapted from Boyle, 2015; Boyle, 2018)	Hybrid warm up	**Fascia Mobilization:** Self-myofascial release exercises to decrease fascia density and reactivity **Mobility:** Static stretching exercises followed by dynamic stretching **Activation:** Neuromuscular pre-activation exercises, postural stability and strength with body weight **Explosive Activities:** Plyometrics, agility and speed drills
(Berdejo-del-Fresno, 2011)	General and specific warm-up for basketball	**General:** Proprioception exercises, mobility, aerobic exercise, static stretching and dynamic stretching **Specific:** Reduced game exercises, free shooting in the basket and layups
(Longo et al., 2012)	FIFA 11+ basketball warm-up	**Temperature Elevation:** Running exercises with varied displacements **Prophylactic Activities:** Strength, balance and jumping exercises **Specific Tasks:** Exercises with specific movement patterns using changes of direction and explosive tasks

PAP: Post-activation potentiation; PAPE: Post-activation performance enhancement.

Warm-Up in Training Sessions

In day-to-day training sessions, warm-up routines can be broken down according to the biomotor capacity being improved. When you want to train agility, speed and cardiovascular endurance sessions on the court, the most recommended thing is to use warm-ups with similar formatting to matchdays (Gonçalves, 2021).

However, in the training sessions in the weight room, the warm-up procedures show some changes and common points. Traditionally, it is accepted that when warming up for strength training, one or two sets of the exercise itself are used, but with a priority submaximal load intensity. This specific warm-up condition generates adequate neuromuscular activation for the target load that will be worked on (Abad et al., 2011; Ribeiro et al., 2014; Eken, 2021; Ribeiro et al., 2021).

Despite this report, in the training of muscle strength and power, general and specific warm-ups must be present. It seems that when we compare the specific warm-up (only the execution of the strength exercise with a load around 50% and 70% of the maximum load) with the general and specific warm-up (20-minutes on the stationary bike at 60% of the maximum heart rate, combined with the specific warm-up mentioned), the maximum strength values in the leg press exercise tend to show better results in combined use. In fact, the combination of general and specific warm-ups are more promising for maximal strength training than specific warm-ups alone (Abad et al., 2011). Still, there are conflicting views in the studies. For example, the systematic review by Ribeiro et al. (2021) reports that strength training for upper or lower limbs is not directly influenced by the type of warm-up (general or specific).

Warming up with hybrid characteristics in strength and power training is a tool that is being universally accepted in practice. Functional warm-up methods that encompass fascia mobilization, mobility, neuromuscular pre-activation and explosive activities have increasingly solidified (Judge et al., 2011; Boyle, 2015; Boyle, 2018).

In the competitive season, teams face the so-called congested microcycles, where there is a high density of games in a short period. In these weeks, there is little time available to train and recover. Thus, in warm-up routines, it is possible to apply training microdoses with tasks of different biomotor capabilities. In the real environment, one can maintain the full duration of the warm-up and substitute exercises or extend this time by including additional microdosing exercises. It is worth mentioning that warm-ups with microdose exercises are short-lived and high-intensity, as well as managing to maximize the use of time (Vretaros, 2022).

Warm-Up on Match Days

Pre-competitive warm-up represents an extraordinary condition of training sessions (Issurin, 2008; Platonov, 2008). The duration of a basketball game is 40-minutes, divided into four quarters of ten minutes (FIBA, 2022). Therefore, the pre-competitive warm-up should be aimed at medium and long-term performance, regardless of whether players are starters or substitutes (Berdejo-del-Fresno, 2011).

When administering the pre-match warm-up, it is vital to calculate the time between the start of the warm-up and the start of the game. Planning this calculation helps not to compromise the warm-up work, because if there is an inadequate time estimate, it will be necessary to speed up the warm-up exercises, or there will be too much time left between the end of the warm-up and the start of the game, taking the athletes to a situation of cooldown (Santos et al., 2020).

Regarding the pre-game warm-up routine, it would be advisable to maintain the usual protocols used in training sessions. Pre-competitive warm-up designs that deviate greatly from what athletes are used to can result in undesired game effects. According to Gonçalves (2021), the warm-up used in games and training tends to be similar, but suffer changes in the total duration.

Multicomponent warm-up for injury prevention is used by 72.0% of formative basketball coaches on game days (Räisänen et al., 2021). Thus, pre-competitive warm-up continues as a procedure that facilitates maximum performance, preparing the physical and mental state of athletes for high functional responses (Powers & Howley, 2014).

Re-Warm-Up During the Game

In the basketball game, we have five players from a team on the court and seven other reserve athletes sitting on the bench. Reserve players can replace the starters at any time during the game, according to needs, as the number of substitutions is infinite (FIBA, 2022). At this point, we have a real problem commonly faced by teams: the time spent on the bench by reserve players. The longer the time spent sitting on the bench, the greater the loss of the physiological effects of the warm-up (Galazoulas et al., 2012; Santos et al., 2020). This barrier exists because the rules only allow the coach to move in the technical area (FIBA, 2022).

The first player substitutions tend to occur after 3-6-minutes of the start of the game. The reason that leads the coach to replace the athletes depends on technical, tactical, fouls and/or injuries. Therefore, many reserve players would be subject to remain seated for several minutes during the match, inducing them to present a deteriorated performance when they enter the game (Alberti et al., 2014). An analysis in four international basketball leagues showed that the average time that a reserve player remains seated on the bench before entering the second quarter of the game is 20-minutes (Santos et al., 2020).

Elite basketball players participated in an experiment where they all performed a standardized warm-up with a total duration of 27-minutes (7.5-minutes of general warm-up, 8.5-minutes of dynamic stretching and 11.0-minutes of specific warm-up) during four consecutive days. Each day after the warm-up, a passive interval sitting on the bench was used (10-minutes, 20-minutes, 30-minutes and 40-minutes). Immediately after the warm-up and right after the break, the athletes were evaluated in the explosive strength of lower limbs (vertical jump), body temperature, blood lactate and 20-meter sprint. Results showed a linear decline in vertical jump height from 13% in the 10-minute period to 20% in the 40-minute sitting period. The 20-meter sprint test also saw a substantial drop that fluctuated from 3.9% in the 10-minute period to 6.3% in the 40-minute sitting period. In addition, body temperature and blood lactate levels gradually decreased as the rest interval increased (Galazoulas et al., 2012).

The condition of reserve athletes was simulated in a research developed by Alberti et al. (2014). Players participated in a 15-minute warm-up (3-minute running, 2-minute dribbling, 6-minute shooting, 3-minute passing) and then divided into five groups: control (active individuals after warm-up), sitting (inactive on the bench), standing (remained static standing), sitting with muscle reactivation (isometric muscle activation in the quadriceps) and spine mobilization (mobilization of the lumbar spine). After the warm-up and after the 20-minute break in each of the five conditions, the athletes were tested in the vertical jump and repeated jumps. In the results, the authors showed that the control group that remained active had no significant loss in the vertical jump tests. However, the group sitting on the bench declined 8.4% in the vertical jump and 10.4% in the repeated jumps. In addition, the muscle reactivation and spine mobilization groups showed performance decreases in jump tests very similar to the sitting group.

The use of mini-bands for neuromuscular activation in reserve players who are sitting for a long time is perhaps a resource that can collaborate with the deleterious effects of cooling down (Gonçalves, 2021). Such an approach can be valuable, as in basketball reserve players must sit still.

In view of what was mentioned above, it is speculated that monitoring the time sitting on the bench of reserve players during a game is a relevant burden for the physical trainer to be aware of. Players who remain inactive for long periods on the bench during the match, when they go to play will likely have a reduction in athletic performance capacity.

Re-Warm-Up in the Game Interval

Before a game, it is a consensual practice to use pre-competitive warm-up. However, a warm-up between game breaks is not yet rooted in the basketball sports scene (Pociūnas et al., 2018).

Therefore, the break between the second and third quarters of the basketball game is seen as a challenging supplementary problem. This regulatory break lasts approximately fifteen minutes (FIBA, 2022). This short period of time can decrease muscle temperature, impairing physical and cognitive performance in the second half of the game (Gaetano & Gaetano, 2017; Racinais et al., 2017; Santos et al., 2020).

The game break is a propitious moment for the recovery of the athletes, through hydration, passive recovery and tactical instructions (Towlson et al., 2013; Edholm et al., 2014). Despite this, it is necessary to seek intelligent re-warm-up strategies, as the game interval significantly decreases muscle temperature by around 2.0°C (Mohr et al., 2004; Towlson et al., 2013; Racinais et al., 2017).

In basketball, if players remain inactive for the entire halftime period, it could result in a sub-optimal state of readiness to play the second half of the game. Two adversities could emerge in the second half of the match, such as a lower work capacity of the athletes and the increased risk of injuries (Hammami et al., 2016; González-Devesa et al., 2023). Thus, there must be an agreement between the members of the coaching staff, so that the players engage in a re-warm-up routine in this interval of the game, to maintain satisfactory levels of muscle temperature (Towlson et al., 2013).

Table 2
Suggestion of re-warm up in the basketball game interval.

Pedagogical Approach	Duration
Passive recovery for hydration, organic restoration, medical treatments and tactical instructions	7-minutes
Active re-warm up (moderate intensity tasks, calisthenics, plyometrics, maximal strength, multidirectional sprints, ballistic activities, etc.)	5 minutes
Specific movement on the court with passes, free shooting, jumps	2 minutes
Active recovery interval before game restart	1 minute

Several interval re-warm-up routines in team sports have been suggested by researchers: 1)- re-warm-up with moderate intensity tasks (~70% of maximum heart rate), 2)- re-warm-up with eccentric strength training, 3)- re-warm-up with plyometrics, 4)- re-warm-up with change of direction exercises, 5)- re-warm-up with PAP protocol, 6)- re-warm-up with multidirectional sprints,7)- re-warm-up with calisthenics exercises, 8)- re-warm-up with ballistic exercises, 9)- re-warm-up with reduced games, 10)- re-warm-up with maximal strength exercises, 11)- re-warm-up combining plyometrics, short distance sprints and changes of direction, 12)- re-warm-up combining accelerations and vertical jumps and, 13)- re-warm-up combining aerobic exercises and PAP. A large portion of these interventions have reported positive results in the preservation of subsequent explosive efforts (Mohr et al., 2004; Zois et al., 2013; Edholm et al., 2014; Hammami et al., 2016; Abade et al., 2017; Pociūnas et al., 2018; Russell et al., 2018; Fashioni et al., 2020; Christaras et al., 2023). Linked to this, re-warm-up causes evolution of technical-tactical parameters, greater possession of the ball in the second half of the game and high average displacement speed (Edholm et al., 2014; González-Devesa et al., 2023).

In basketball, in particular, the results of two studies have been contradictory. In a first research, with female players of formative category, it was found that a short re-warm-up with 6-minutes of passive recovery, followed by 1-minute of explosive activities and 2-minutes of free shooting did not affect the height of the vertical jump (González- Devesa et al., 2023). In contrast, in the second investigation with college players, effective re-warm-up at half-time consisted of aerobic exercise combined with PPA (Pociūnas et al., 2018).

Thus, a halftime re-warm-up in modern basketball needs to be consistent. This is both practically applicable and time-efficient for it to be successful (Fashioni et al., 2020; González-Devesa et al., 2023). Based on some of the aforementioned research gathered, we were able to suggest the following re-warm-up routine to be employed: 7-minutes of passive recovery to minimize accumulated fatigue, 5-minutes of active re-warm-up in the locker room or court, 2-minutes of passes and free shooting on court and, 1-minute break with active recovery before the game restarts (Table 2).

Conclusion

It is well documented that warm-up is a fundamental part of preparatory activities for training sessions and games. Administering rational warm-up and re-warm-up routines, with an appropriate design, is the function of the basketball team's physical trainer. However, there is no consensus among experts on what would be the most ideal functional warm-up and re-warm-up routine. However, several protocols have been suggested by publications to be used in team sports.

When prescribing warm-up routines, seven basic methodological variables need to be observed: duration, intensity, adopted exercises, sequence of tasks, use of additional equipment, number of routines and recovery intervals. The most critical moments to reflect on the implementation of warm-up routines would be the following: warm-up in training sessions, warm-up on match days, re-warm-up during the game, re-warm-up at half-time. Each of these points requires a different didactic-pedagogical approach in warm-up procedures. In the warm-up culture, such key elements need to be aligned with the situations and relational dynamics that arise.

In a realistic context, numerous factors can emerge that directly interfere with the smooth running of warm-up routines. From the acquisition of a broader view of each component involved in this process, it becomes feasible to resolve these issues and, with that, implement warm-up interventions with a more concrete and relevant transfer to the exercise of professional

practice.

Authors' Contribution

Study Design: AV; Data Collection: AV; Statistical Analysis: AV; Manuscript Preparation: AV.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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