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The Effect of Different Warm-Up Protocols in Repeated Sprint Ability Performance in active young adults

Mestrado em Treino Desportivo para Crianças e Jovens

José Hugo Bernardes Colares Pinto, Julho 2013

UNIVERSIDADE DE COIMBRA

Faculdade de Ciências do Desporto e Educação Física

The Effect of Different Warm-Up Protocols in Repeated Sprint Ability Performance

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Orientador: Professor Doutor Luís Manuel Pinto Lopes Rama.

José Hugo Bernardes Colares Pinto

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Abstract

Although little scientific evidence supports its effectiveness, warm up is a widely accepted practice preceding training session or every athletic event. The aim of this study is to examine the effectiveness of different warm-up protocols in repeated sprints test. Fifty participants performed the Repeated Sprint Ability test 4 times in different days. Before each test the participants performed one of the 4 protocols randomly chosen, one with aerobic running and joint mobilization (C), one including aerobic running and static stretches (SS), one with aerobic running and dynamic stretches (DW) and a control one without warm-up (NW). The 4 protocols were compared using 4 indicators of performance in the RSA test (first sprint, fastest sprint and fatigue index). We hypothesized that no significant differences between protocols in fatigue index will be find, and better results in first and fastest sprint for protocols DW e C and worst results for SS protocol.

Keywords: Warm-up, repeated sprint ability, dynamic stretch, static stretch, running.

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Introduction

Warm up is a widely accepted practice preceding nearly every athletic event (Bishop, 2003; Girard, Carbonnel, Candau, & Millet, 2009; Mandengue, Seck, Bishop, Cisse, & Ahmaidi, 2005), and take a significant part of the practice in many sports.

In literature, warm-up is proposed for three main objectives: a) increase the physical and physiological readiness of the athletes, b) decrease injury incidence and increase injury resilience and c) enhance sport performance (Cone, 2007). Usually, in many sports, it has an initial phase of general active warming, a second one of active flexibility and a final phase of neural preparation with exercises similar to competition.

Nevertheless, despite warm-up is considered essential for optimum performance and to prevent injury by common sense, there is little scientific evidence supporting its effectiveness (Bishop, 2003). Furthermore, is not clear the perfect structure for warm-up: what are the best exercises, which duration and intensity.

Since 50's, researchers try to demonstrate the importance of warm-up in sport domain, but recently the number of studies about this topic as increased exponentially. An important number of papers as focus on the influence of warm-up in performance (Girard et al., 2009; Gregson, Batterham, Drust, & Cable, 2005; Sotiropoulos et al., 2010; Yaicharoen, Wallman, Bishop, & Morton, 2012; Zois, Bishop, Ball, & Aughey, 2011), the role of the flexibility exercises as a component of the warm-up (Little, Thomas; Williams, 2006; Murphy, Di Santo; Alkanani & Behm, 2010; Pearce, Kidgell, Zois, & Carlson, 2009; Silveira, Gayle; Sayers, Mark; Waddington, 2011; Taylor, Sheppard, Lee, & Plummer, 2009; Pearce, Latella, & Kidgell, 2012; Wong, Chaouachi, Lau, & Behm, 2011), and the role of warm-up in the injury prevention (Fradkin, Gabbe, & Cameron, 2006; Woods, Bishop, & Jones, 2007), however, contradictory results remain.

The purpose of this study is examine the effectiveness of different warm-up protocols in repeated sprints, aiming to add some knowledge in the understanding of which exercises are suitable for use in warm-up.

The sample is composed by active but non-athletes individuals, because athletes are very experienced in the use of some types of warm-up protocols which could skew and contaminate the results. The no warm-up protocol (NW) condition will be used as a control, to access the influence of warm-up over performance; the two protocols with stretches will be used to compared their effectiveness over performance; in the stretches protocols will be added a running bout of exercise because, in practice, stretches are always supplementary to other exercises; the running and joint mobilization protocol (C) will be used to compare with the stretches protocols, and no warm-up to revise some studies that report better performance with aerobic based warm-up (Girard et al., 2009). The RSA will be used because is a recognized test in the scientific community that evaluates lactic and alactic capacity. Furthermore, there are few papers that use this test to compare warm-up protocols. The RSA variables that we used are the best sprint, mean sprint, total time of sprints and fatigue index (decrement score).

We hypothesized worse results in the fastest sprint, mean sprint and total time of sprints in Static Stretches protocol (SS) and in no warm-up protocol (NW). In those three variables are expected best results in DS and in the control protocol (C), but we don't have previous findings to know which is more effective. As there are no papers published with this methodology, there are no evidences about the results in the fatigue index. However no differences will be expected between protocols because these warm-ups are supposed to don't produce fatigue.

Backgroung

Warm-Up

Warm-up techniques can be broadly classified into two major categories: passive warm-up or active warm-up (Bishop, 2003).

Passive warm-up involves raising body temperature using various methods like hot showers or baths, saunas and heating pads. Despite being less practical for most athletes it has been used to test the hypothesis that many of the performance changes associated with warm-up can be largely attributed to temperature-related mechanisms (Bishop, 2003). "Active warm-up involves exercise and is likely to induce greater metabolic and cardiovascular changes than passive warm-up"(Bishop, 2003). This author categorizes the active warm-up effects in two different groups: Temperature related and Non-temperature related.

Table 1- Temperature related warm-up effects (Bishop, 2003)

Temperature related warm-up effects	
Metabolic effects of active warm-up	Viscous resistance of muscles and joints varies within temperature differences; by increasing muscle temperature, muscle viscous resistance decreases.
Increased oxygen delivery to muscle	Muscle temperature rises can increase oxygen delivery.
Speeding of rate-limiting oxidative reactions	Increased muscle temperature elevates oxygen consumption of isolated mitochondria.
Increased anaerobic metabolism	An increase in muscle temperature increases muscle glycogenolysis, glycolysis and high-energy phosphate degradation during exercise.
Increase nerve conduction rate	Increased muscle temperature improves central nervous system function and increases the transmission speed of nervous impulses

Table 2 - Non-temperature related warm-up effects (Bishop, 2003)

Non-temperature related warm-up effects	
Metabolic effects of active warm-up	Oxygen delivery to the muscles may also be affected by a number of metabolic changes that occur in response to active warm up
Elevation of baseline oxygen consumption (VO_2)	Warm-up may allow subsequent tasks to begin with an elevated baseline VO_2. Consequently, less of the initial work will be completed anaerobically, leaving more of the anaerobic capacity for later in the task.
Post activation potentiation	The performance of skeletal muscle is affected by its contractile history. Post activation potentiation is the transient increase in muscle contractile performance following previous “conditioning” contractile activity.
Breaking of Actin-Myosin Bonds	Part of the explanation for the stiffness of resting muscle may involve stable bonds between actin and myosin filaments. However, with physical activity many of the bonds are broken, and muscle stiffness decreases.
Psychological Effects	Warm-up provides valuable time for athletes to mentally prepare for their event. Related to this, warm-up can possibly be considered part of a pre-performance routine, assisting the athlete to obtain an appropriate activation state.

Cone, J. (2007) proposes 3 phases for warm-up in intermittent endurance sports like soccer. The first phase is “active warming”, the primary goal is the elevation of muscle temperature, hearth rate and VO2. This phase consist of primarily low-level activities like jogging and some shuffling actions.

The second phase is “active flexibility”, it targets the maintenance of the effects of active warming, and the progression of musculoskeletal and neuromuscular preparedness for the training session or competition to follow. This phase consist in 3 types of activities: assisted dynamic activities, predominantly single-joint movements, performed at low speeds, with the muscle and joint typically being taken through a given range of motion in an assisted fashion; controlled dynamic activities, single-joint to multi-joint movements performed at moderate speeds, with the muscle and joint ROM being controlled by both body position and body weight; antagonistic dynamic activities, primarily multi-joint activities at high speeds, with the muscle and joint ROM being controlled primarily by the antagonistic muscle group.

The last phase is “neural preparation”, it consists in a neurological preparation and athletic development of the players via the training of speed, agility and quickness components.

Physiology of stretch

Skeletal muscles

Skeletal muscles vary in shape and size. The central portion of whole muscle is called the belly. The belly comprises smaller compartments called fasciculi (Alter, 2004).

Each muscle fiber constitutes a single muscle cell. When viewed under microscope, individual muscle fibers have banded or striated structure. This banding pattern reflects the ultrastructural organization of each myofibril. To understand how muscles contract, relax and elongate, one must understand the structure of the myofibril (Alter, 2004).

Myofibrils

Each muscle fiber contains several hundred to several thousand myofibrils. These are the contractile elements of skeletal muscle. Myofibrils appear as long strands of still smaller units – sarcomeres.(Wilmore, Costill, & Kenney, 2008)

A sarcomere is the basic functional unit of a myofibril and the basic contractile unit of the muscle.

Myofibrils comprise even smaller structures called myofilaments or filaments for short. Originally, two types of filaments, one thin (actin) and one thick (myosin), were thought to exist within the sarcomere. However, after years of research a third filament, titin, was discovered (Alter, 2004).

Titin is a giant protein that spans half of the striated muscle sarcomere. Titin constitutes about 10% of myofibril mass. The length and size of titin appears to be an important factor in determining when sarcomeres will develop resting tension and where the sarcomere will yield under stress(Alter, 2004).

Physical basis of contraction

The best-known theory, the sliding filament theory, asserts that when the myosin cross-bridges are activated, they bind with actin, resulting in a conformational change in the cross-bridge, which causes the myosin head to tilt and to drag the thin filament toward the center of the sarcomere (Wilmore et al., 2008). The pulling of the thin filament past the thick filament shortens the sarcomere and generates force (Wilmore et al., 2008). A maximally contracted sarcomere may shorten from 20% to 50% of its resting length. When passively stretched, it may extend to about 120% of its normal length. Researchers have concluded that change in muscle length must result from the sliding of the thick and thin filaments along each other (Wilmore et al., 2008).

Theoretical limit of muscular elongation

Muscular fibers are incapable of lengthening or stretching themselves. A force must be received from outside the muscle, such as gravity, momentum (motion), the force of antagonistic muscles, or the force provided by another person or by some part of one’s own body (Alter, 2004).

The increase is more than 50% of the resting length. The contractile component of the muscle can then increase by 67%. This extensibility enables our muscles to move through a wide ROM (Alter, 2004).

Potential Factors Influencing Flexibility (ROM) (Alter, 2004)

ROM is restricted or impaired by a variety of factors, the important for sports science are:

- Lack of elasticity of connective tissues in muscle or joints;
- Muscle tension;

- Reflexes;
- Lack of coordination and strength in the case of active movement;
- Limitations imposed by other synergistic muscles;
- Length of ligaments and tendons;
- Bone and joint structure limitations;
- Gender (e.g., pelvic structure);
- Pain (stretch threshold or tolerance);
- The presence of any simultaneous movement in another position;
- Temperature;
- Age;
- Ethnic origin;
- Training;
- Circadian variations;
- Personal activity patterns (e.g., poor posture sitting);
- Warm-up.

Stretch Classification

Stretching can be done either actively or passively. Active stretching occurs when the person doing the stretch is the one holding the body part in the stretch position (Nelson & Kokkonen, 2007). Passive stretching occurs when someone else moves the body part of the person to the stretch position and then holds the stretch for a set of time (Nelson & Kokkonen, 2007).

Table 3 - Stretch classification(Nelson & Kokkonen, 2007)

Stretch classification	*Stretch description*
Static stretch	Is when one stretches a particular muscle or group of muscles by slowly moving the body part into position and then holding the stretch for a set time.
PNF (proprioceptive neuromuscular facilitation)	Is a stretching technique in which a fully contracted muscle is stretched by moving a limb through the joint's range of motion.
Ballistic stretch	Uses muscle contractions to force muscle elongation through bobbing movements where there is no pause at any point in the movement.
Dynamic stretch	Is similar to ballistic stretching in that both use fast body movements to cause muscle stretch, but dynamic stretching does not employ bouncing and bobbing.

Stretching Duration

Many programs recommended holding each stretch for 6 to 12 seconds. However, 10 to 30 seconds is also commonly recommended. The problem with holding stretches for longer than 30 seconds is that stretching programs might last longer than many workouts.

Stretches lasting for longer than 30 seconds seem to be uncomfortable for some athletes.

30 and 60 seconds of stretching were more effective at increasing hamstring flexibility than stretching for 15 seconds or no stretch at all. In addition, no significant difference existed between stretching 30 seconds and for 1 minute, indicating that 30 seconds of stretching the hamstrings muscle was as effective as the longer duration of 1 minute.

A stretch normally takes about 30 seconds to progress from middle of the muscle belly to the tendons. When a passive muscle and its tendons are stretched, initially most of the movement is taken up by the tendon and only when tension begins to rise are the muscle fibers themselves stretched. The American College of Sports Medicine Position Stand (1998) proposes that static stretches should be held for 10 to 30 seconds.

Stretching Intensity

The correct target intensity of stretching is extremely significant because, like any form of training, it can provide a potentially traumatic stimulus to the muscle-tendon unit. Like other forms of training, acute stretching programs can result in the structural weakening of the muscle-tendon unit and increase the risk of injury.

Stretching should always be performed at low-intensity level of approximately 30% to 40% of perceived exertion.

Although stretch may produce some discomfort (especially for beginners), it should not be so great a discomfort to cause pain.

The use of stretching exercises during Warm-up routines.

Through the years it has been studied the role of stretches on warm-up. Usually, there are two types of stretches used in warm-up: dynamic and static.

Many studies compare dynamic and static stretch with performance tests but there are few answers. Concerning static stretching there are a considerable amount of research about their efficacy in warm-up in relation to performance, with some investigators proposing eliminating this traditional part of the warm-up (Young, 2007). But to apply research findings on stretches to pre-competition or training warm-ups, it is important that stretching be investigated using protocols that are realistic and reflective of athletic practices (Young, 2007), and many of the studies don't. And when we want to cross data from different studies their protocols don't match (they diverge in duration of each stretch, duration of warm-up, intensity of stretch, intensity of the warm-up, warm-up exercises, etc).

Table 4 – Performance comparison between Static Stretch (SS), Dynamic Stretch (DS) and Control (C) in Sprint

References	*n*	*Static Stretch protocol*	*Intensity of Static Stretch*	*Significant Results*
Fletcher & Jones (2004)	97	Passive SS 1x20s Active SS 1x20s	PMD	↑ DS in 20m sprint ↓SS active or passive in 20m sprint
Nelson, Driscoll, Landin, Young, & Schexnayder (2005)	16	SS 4x30s	Discomfort similar to that normally felt during their daily stretching activities	↓SS in 20m sprint
Faigenbaum et al. (2006)	18	2x30s	PMD	No differences

Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman, (2006)	30	SS group 2x30s SS + Dy group 1x30s	PMD	↓SS on 10-yards run compared with Dynamic warm-up and Static plus Dynamic warm-up
Little & Williams, (2006)	18	1x30s	Until approach end of the ROM within the pain threshold	↑SS 20-m sprint compared with C SS no differences in 10-m stationary ↑DS 10-m stationary, 20-m flying sprint
Fletcher & Anness (2007)	18	3x22s	PMD	↓SS in 50-m sprint
Vetter (2007)	26	2x30s	NR	No differences in 30-m sprint
Winchester et al. (2008)	22	3x30s	Point of Discomfort	↓SS in 40-m sprint
Taylor et al. (2009)	13	2x30s	Point of the minor discomfort	↓SS in 20-m sprint
Y. Sim et al. (2009)	30	2x20s	Point of slight discomfort	No differences, the mean values in total sprint time were generally slowest in Dy-SS
Rodríguez, Francisco & Andújar (2010)	28	2x30s	NR	↓SS all sprints
Pearce et al. (2012)	15	1x30s	NR	No differences
Samson et al. (2012)	19	3x30s	PMD	No differences

PMD Point of Mild Discomfort, NR Not Reported

Table 3 is a comparison of some of the last studies with static and dynamic stretch in sprint. In most of this studies are reported sprint performance impairments; in fact, just five of these studies (Faigenbaum et al., 2006; Little, Thomas; Williams, 2006; Pearce et al., 2012; Samson et al., 2012; Vetter, 2007) don't show these results. Comparing protocols, we can see a pattern in the different samples; only one study with male athletes has not shown performance impairments related to static stretch (Little, Thomas; Williams, 2006), and the warm-up protocol of this study have sport specific exercises after the static stretch that can restore the static stretch related impairments. The other studies who doesn't show static stretch related impairments have a mixed sample (male and female) (Faigenbaum et al., 2006; Samson et al., 2012; Vetter, 2007) or male non-athletes (Pearce et al., 2012).

From these results we can infer that the static stretch related impairments in sprint may be proportional to muscle mass, the subjects with more muscle mass have more stretch related impairments than the ones with less.

Some studies reported improvements after dynamic stretch (Fletcher & Jones, 2004; Little, Thomas; Williams, 2006). We can't say for sure that dynamic stretch improves performance in sprint but there is some evidence in favor.

Table 5 – Performance comparison between Static Stretch (SS), Dynamic Stretch (DS) and Control (C) in Jump

References	***n***	***Stretch protocol***	***Intensity of Static Stretch***	***Significant Results***
Faigenbaum et al., (2006)	18	2x30s	PMD	↓SS in vertical and long jump
Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman (2006)	30	SS group 2x30s SS + Dy group 1x30s	PMD	↓SS in vertical and long jump compared with Dynamic warm-up and Static plus Dynamic warm-up
Little, Thomas & Williams (2006)	18	1x30s	Until approach end of the ROM within the pain threshold	No significant difference
Vetter (2007)	26	2x30s	NR	↓SS in CMJ
Taylor et al. (2009)	13	2x30s	Point of the minor discomfort	↓SS in VJ
J. C. Murphy et al. (2010)	42	1x20s	NR	No differences between SS and DS in VJ
Fletcher & Monte-Colombo (2010)	21	1x15s	PMD	↓ SS in jumps compared with DS and control ↑DS in jumps compared with SS and control
Faigenbaum et al. (2010)	19	3x20s	Point just before mild discomfort	↓SS in VJ until 18 minutes
Pearce et al. (2012)	15	1x30s	NR	↓SS jumps DS non-significant difference compared with C ↓SS compared with DS and control After movement activity,

				SS jumps returned to baseline values
Samson et al. (2012)	19	3x30s	PMD	No differences

PMD Point of Mild Discomfort, NR Not Reported

In table 4 we have a comparison of some of the last studies with static and dynamic stretch in jump. Most of the studies reported static stretch related impairments in jump performance. Again, there are a protocol relation, the three studies that have no impairments, have sport specific exercises after static stretch (Little, Thomas; Williams, 2006), non-athletes sample (J. C. Murphy et al., 2010) or a mixed sample (male and female) (Samson et al., 2012).

Table 4 shows some evidence that dynamic stretch can improve jump performance (Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman, 2006; Fletcher & Monte-Colombo, 2010).

Tables 5, 6 and 7 show performance comparison in range of motion (ROM), agility and strength.

In ROM there are some evidence in favor of stretch protocols comparing with control groups (Rodríguez, Francisco; Andújar, 2010; Samson et al., 2012) and better results with static stretch protocol compared with dynamic (Samson et al., 2012).

In agility tests there are different results one study report dynamic stretch related improvements (Little, Thomas; Williams, 2006), other no significant differences (Faigenbaum et al., 2006) and other static stretch related impairments (Pearce et al., 2012). These findings are similar with the sprint and jump results, but more research is needed to infer something.

In Strength there are some studies who show static stretch related impairments (Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman, 2006; Sekir, Arabaci, Akova, & Kadagan, 2010; Yamaguchi et al. 2006), some with no differences (Faigenbaum et al., 2006, 2010) and one that shows performance improvements after dynamic stretch protocol (Sekir et al., 2010).

Table 6 – Performance comparison between Static Stretch (SS), Dynamic Stretch (DS) and Control (C) in ROM

References	*n*	*Stretch protocol*	*Intensity of Static Stretch*	*Significant Results*
J. C. Murphy et al. (2010)	42	1x20s	NR	No differences in ROM between groups
Rodríguez, Francisco & Andújar (2010)	28	2x30s	NR	↑SS ROM ↑DS ROM
Samson et al. (2012)	19	3x30s	PMD	↑SS ROM compared with DS

PMD Point of Mild Discomfort, NR Not Reported

Table 7 – Performance comparison between Static Stretch (SS), Dynamic Stretch (DS) and Control (C) in Agility

References	*n*	*Stretch protocol*	*Intensity of Static Stretch*	*Significant Results*
Little, Thomas & Williams (2006)	18	1x30s	Until approach end of the ROM within the pain threshold	SS no difference compared with C ↑DS in zig zag course
Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman (2006)	30	SS group 2x30s SS + Dy group 1x30s	PMD	No differences between groups in pro-agility shuttle run
Pearce et al. (2012)	15	1x30s	NR	↓ SS in 505 test compared with DS and C

PMD Point of Mild Discomfort, NR Not Reported

Table 8 – Performance comparison between Static Stretch (SS), Dynamic Stretch (DS) and Control (C) in Strength

References	*n*	*Stretch protocol*	*Intensity of Static Stretch*	*Significant Results*
Faigenbaum et al. (2006)	18	2x30s	PMD	No differences in seated medicine ball toss
Yamaguchi et al. (2006)	12	4x30s	Point at which the subject felt discomfort	↓SS reduced power output under various loads
Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas	30	SS group 2x30s SS + Dy group 1x30s	PMD	↓SS on medicine ball toss

A;Hoffman (2006)				
Faigenbaum et al. (2010)	19	3x20s	Point just before mild discomfort	No significant differences in medicine ball toss
Sekir et al. (2010)	10	2x20s	Threshold of mild discomfort	↓SS muscle strength ↑DS muscle strength

PMD – Point of Mild Discomfort

Methods

Sample

In this study we used a sample of 22 Caucasian subjects, all healthy, non-athletes (they don't practice organized sport for 1 year or more). All the participants were informed about the characteristics of the test and all of them will fulfill an informed consent. They will be informed to maintain their normal diet, but not to ingest caffeine or alcoholic drinks in the previous 12 hours of the tests, and to not do intensive work-out in the previous 24h of the tests. A sample description is made in table 8.

Table 9– Sample description (Decimal age and BMI)

N	*Age*	*BMI*
22	23,31 ±2,18	22,49 ±2,05

Design

The subjects went to the gym in four different occasions to perform the different protocols randomly. Each time, they have done one protocol of warm-up followed by the RSA test. All the tests were made in the same gym at the same hour approximately. The tests and the protocols of warm-up were conducted by the same supervisor. There were 24h minimum between each test, and will not take more than 3 weeks long in each subject complete the all protocols.

Protocol

Repeated Sprint Ability (RSA)

The RSA test protocol consisted of seven maximal 34.2 m sprints, with 25s of active recovery between sprints (Abrantes, Maçãs, & Sampaio, 2004). Each sprint was performed with a change in direction (Figure 1). Photoelectric cells (Brower timing sprint testing system SpeedTrap II) were used to measure the subjects' performance and to increase test reliability. Following each sprint there will be a period of active recovery (25 s to cover a distance of 40 m), which consisted of jogging. Recovery was timed with a basic chronometer in order to ensure that subjects return to the initial point of the course in time. Additionally, it was given verbal feedback at 5, 10, 15 and 20s of the recovery. Performance was measured by the mean sprint, the fastest sprint, total time of sprints and the fatigue index calculated with the performance decrement during the test.

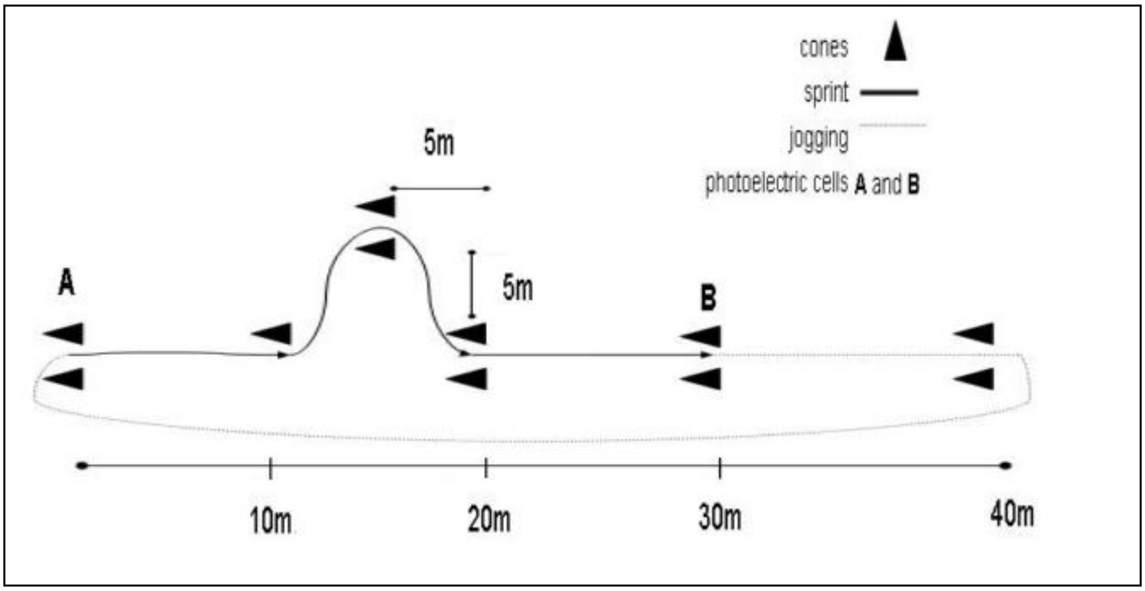


Figure 1 - Diagram of Repeated Sprint Test

Warm-up Protocols

There were 4 warm-up protocols that subjects will do in random order, one is without Warm-up (NW), one with 7 minutes of aerobic running and 8 minutes of static stretching (6 exercises for lower limb, 30 seconds each) (SS), one with 7 minutes of aerobic running and 8 of dynamic stretching (6 exercises for lower limb in movement) (DS), and another with 15 minutes of aerobic running and joint mobilization (C). They are described in tables 9, 10 and 11.

Table 10 - Static stretch protocol (SS) (adapted from Pearce et al., 2012) 8’ exercises + 7’ jogging

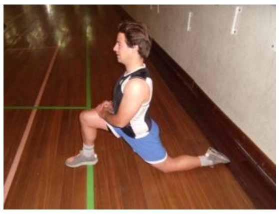
Stretch	*Sets*	*Time/repetition/ distance*	*Example*
Seated single leg hamstring. In a seated position with one leg straight, place the other leg on the inside of the straight leg and reach forward	2	30 s stretch	
Single leg gastrocnemius. In a standing position with ankle in 458 approximately 1 m from the wall, lean against the wall with both hands, keeping the leg straight	4	30 s stretch (twice each leg)	
Seated single gluteal. Seated on the floor with the outside of the lower leg bent in front and the inside of the opposite leg bent to the side. Position the bottom of the forward foot against the knee of the opposite leg.	2	30s stretch	
Hip/thigh flexor lunge. Standing in a forward lunge position (as wide apart as is comfortably possible), then lower centre of body slowly until stretch is felt through the hip flexor muscles	2	30s stretch	
Single leg quadriceps stretch. In the standing position with an erect spine, bend one knee and bring heel towards buttocks while holding the foot with one hand	4	30s stretch (twice each leg)	

Table 11 - Dynamic stretch protocol (DS) (adapted from Pearce et al., 2012) 8' exercises + 7' jogging

Stretch	*Sets*	*Time/repetition/distance*
Walking high knee to chest. While walking, lift knee towards chest	3 sets	10 repetitions each leg
Leg swinging - antero-posterior and medio-lateral directions. With the arm outstretched to the side and leaning against a wall, the opposing leg is stretched through full range of movement in the sagittal plane (or coronal plane for medio- lateral direction), undergoing both hip flexion on the forwards motion and hip extension on the backwards motion	4	10 repetitions each leg (2 sets antero-posterior/ 2 sets medio-lateral)
Hurdler's knee raise - forward movement. While travelling forwards, participant raises trailing leg and places hip in flexion (approximately 90º) in an abducted and externally rotated position, with the knee flexed at 90º. In this position the limb is displaced forwards as though stepping over an object just below waist height and returned to normal walking stride position	2	10m
Hurdler's knee raise - reverse movement. Same as above but travelling in reverse direction	2	10m
Heel ups. Rapidly kick heels towards buttocks while walking forward	3	10m

Table 12 - Joint mobilization (C) 8' exercises + 7' jogging

Stretch	*Sets*	*Time/repetition/distance*
Arms rotation (simultaneous)	4	10 meters
Arms rotation (alternately)	4	10m
Wrists and ankles rotation	4	15 seconds
Knee rotation (simultaneous)	4	15s
Knee rotation (assimetric)	4	15s
Waist rotation	4	15s
Neck rotation	4	15s

Data analysis

For statistical analysis, it was carried out a repeated measures ANOVA, using the different warm-up protocols as a factor, with post-hoc test analyses (least square difference) performed where appropriate, to identify differences between protocols in the 4 variables of performance.

Results

The results for RSA mean, RSA best sprint, RSA decrement score and RSA Total time are presented in table 12. There were no significant differences for RSA mean, RSA best sprint, RSA decrement score and for RSA total time between warm-up protocols.

Table 13 - Descriptive statistics for RSA variables (Mean, Best sprint, Decrement Score and Total Time)

	RSA Mean		***RSA Best sprint***		***RSA Decrement Score***		***RSA Total Time***	
	Mean	*Std. Deviation*	*Mean*	*Std. Deviation*	*Mean*	*Std. Deviation*	*Mean*	*Std. Deviation*
SS	7,59	0,41	7,26	0,41	4,60	2,40	53,11	2,87
DS	7,60	0,59	7,24	0,54	5,03	3,01	53,23	4,14
C	7,54	0,46	7,19	0,43	4,91	2,83	52,79	3,19
NW	7,59	0,42	7,27	0,42	4,55	1,91	53,16	2,95

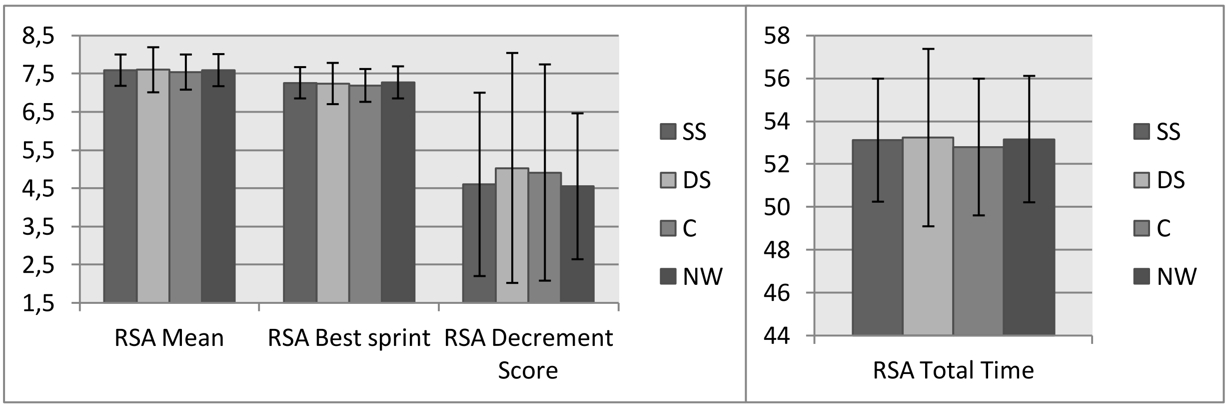


Figure 2– Descriptive statistics for RSA variables (Mean, Best sprint, Decrement Score and Total Time)

RSA mean

For this variable the mean results with SS protocol were 7,59 ± 0,41s, with DS protocol were 7,60 ± 0,59s, with C protocol were 7,54 ± 0,46 and with NW protocol 7,59 ± 0,42.

RSA best sprint

For this variable the mean results with SS protocol were 7,26 ± 0,41s, with DS protocol were 7,24 ± 0,54, with C protocol were 7,19 ± 0,43 and with NW protocol 7,27 ± 0,42.

RSA decrement score

For this variable the mean results with SS protocol were 4,60 ± 2,40, with DS protocol were 5,03 ± 3,01, with C protocol were 4,91 ± 2,83 and with NW protocol 4,55 ± 1,91.

RSA total time

For this variable the mean results with SS protocol were 53,11 ± 2,87, with DS protocol were 53,23 ± 4,14, with C protocol were 52,79 ± 3,19 and with NW protocol 53,16 ± 2,95.

Although no differences were found, figure 2 shows that protocol C had better results than other warm-up protocols in all 3 time variables used (RSA mean, RSA best sprint and RSA total time). In addition, in fatigue index (decrement score) there were two protocols (DS and C) with worst results than the others.

Discussion

Our study was created to access if there were differences in performance with different warm-up protocols in a team sport specific test (Repeated Sprint Ability Test). This methodology intends to provide more information about warm-up in situations with repeated sprints with changes of direction.

It was hypothesized that DS protocol should have better results in the fastest sprint, mean sprint and total time of sprints, and that SS protocol should have worse results in the same variables. Our results don't match with those assumptions, but they are similar with some studies results that reveal no differences between protocols in sprint tests (Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman, 2006; Pearce et al., 2012b; Samson et al., 2012; Vetter, 2007) and Agility tests (Faigenbaum et al., 2006). These different results could be due to this mixed protocol, the test used is not a pure sprint test neither a pure agility test. Other hypothesis is that our sample, like Faigenbaum's (Faigenbaum, Avery D; Kang, Jie; Mcfarland, James; Bloom, Jason M; Magnatta, James; Ratamess, Nicholas A;Hoffman, 2006) Pearce's (Pearce et al., 2012), Samson's (Samson et al., 2012) and Vetter's (Vetter, 2007) sample, don't have only male athletes. This could suggest that male athletes react differently to warm-up than other populations.

Few recent studies had included a group without any warm-up in their methodology. Although warm-up benefits are know (Bishop, 2003) and deeply studied, in our results there was no evidence about that. Some subjects refer that they were uncomfortable doing the test without warm-up, but the NW protocol results were very similar to other protocols, with no significant differences. This may be due to the psychological effect of warm-up described by Bishop (Bishop, 2003), though no effects shown in performance.

Regardless of no differences were present in our study, mean values of the decrement score were in general worst in DS and C protocols, described by the subjects as "more strenuous" protocols.

The study results can't be generalized for team sports because, in team sports, players have many actions besides repeated sprints with changes of direction. But they show that for this repeated sprint ability, with non-athletes, with this different type of warm-up or without warm-up the outcome is similar. We can hypothesize that in non-athletes the warm-up is not relevant for the subsequent activities performance, at least if the activities are repeated sprints.

From the results in the decrement score we can infer that a strenuous warm-up could have a negative effect in the performance maintenance over time in non-athletes, if the type of warm-up is not important, it should be chosen a less strenuous one.

Conclusion

- In repeated sprint ability tests, in non-athletes, warming-up doesn't cause performance impairments.
- Male athletes may react differently to warm-up than other populations.
- Strenuous warm-up could have a negative effect in the performance maintenance over time in non-athletes.

Further research

This study brings more questions than answers. There seems to be a difference between athletes and non-athletes to warm-up, but does this difference exist? What causes these differences? The effect of different warm-up protocols in athletes and non-athletes could be a future research.

Another one is the duration of warm-up. Although this study was made in non-athletes, and no significant differences were found, it seems that strenuous warm-up causes a negative effect in the performance maintenance. Tests for aerobic and anaerobic endurance should be made comparing different warm-up durations.

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Appendix 1

Nome:____

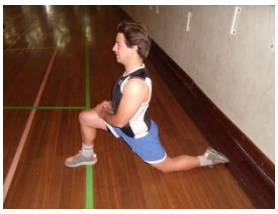
Data de nascimento:________ Nº de telemóvel:_____________________________

Estatura:________ Massa Corporal:________

	1º Teste	2º Teste	3º Teste	4º Teste
Dia				
Aquecimento				
Tempo do 1º sprint				
Tempo do 2º sprint				
Tempo do 3º sprint				
Tempo do 4º sprint				
Tempo do 5º sprint				
Tempo do 6º sprint				
Tempo do 7º sprint				

Observador/es:____

Appendix 2

Static stretch protocol (SS) (adapted from Pearce et al., 2012) 8' exercises + 7' jogging			
Stretch	Sets	Time/repetition/ distance	Example
Seated single leg hamstring. In a seated position with one leg straight, place the other leg on the inside of the straight leg and reach forward	2	30 s stretch	
Single leg gastrocnemius. In a standing position with ankle in 458 approximately 1 m from the wall, lean against the wall with both hands, keeping the leg straight	4	30 s stretch (twice each leg)	
Seated single gluteal. Seated on the floor with the outside of the lower leg bent in front and the inside of the opposite leg bent to the side. Position the bottom of the forward foot against the knee of the opposite leg.	2	30s stretch	
Hip/thigh flexor lunge. Standing in a forward lunge position (as wide apart as is comfortably possible), then lower centre of body slowly until stretch is felt through the hip flexor muscles	2	30s stretch	
Single leg quadriceps stretch. In the standing position with an erect spine, bend one knee and bring heel towards buttocks while holding the foot with one hand	4	30s stretch (twice each leg)	

Apendix 3

Dynamic stretch protocol (DS) (adapted from Pearce et al., 2012) 8’ exercises + 7’ jogging		
Stretch	Sets	Time/repetition/distance
Walking high knee to chest. While walking, lift knee towards chest	3 sets	10 repetitions each leg
Leg swinging - antero-posterior and medio-lateral directions. With the arm outstretched to the side and leaning against a wall, the opposing leg is stretched through full range of movement in the sagittal plane (or coronal plane for medio-lateral direction), undergoing both hip flexion on the forwards motion and hip extension on the backwards motion	4	10 repetitions each leg (2 sets antero-posterior/ 2 sets medio-lateral)
Hurdler’s knee raise - forward movement. While travelling forwards, participant raises trailing leg and places hip in flexion (approximately 90^o) in an abducted and externally rotated position, with the knee flexed at 90^o. In this position the limb is displaced forwards as though stepping over an object just below waist height and returned to normal walking stride position	2	10m
Hurdler’s knee raise - reverse movement. Same as above but travelling in reverse direction	2	10m
Heel ups. Rapidly kick heels towards buttocks while walking forward	3	10m

Joint mobilization (C) 8’ exercises + 7’ jogging	
Arms rotation (simultaneous)	4 x 10 meters
Arms rotation (alternately)	4 x 10m
Wrists and ankles rotation	4 x 15 seconds
Knee rotation (simultaneous)	4 x 15s
Knee rotation (assimetric)	4 x 15s
Waist rotation	4 x 15s
Neck rotation	4 x 15s