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REVISIÓN

STRETCHING EXERCISES IN THE WARM-UP: ROUTINES DESIGNS AND IMPACT ON SPORTS PERFORMANCE

ESTIRAMIENTOS EN EL CALENTAMIENTO: DISEÑO DE RUTINAS E IMPACTO SOBRE EL RENDIMIENTO

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ABSTRACT

Several authors have analyzed the acute effect that different stretching routines used in the warm-up have on sports performance, and the results are often contradictory. These opposing results may be explained according to the different designs of stretching routines as well as the different methodologies the studies have followed. Therefore, the analysis of different stretching program parameters (protocol, technique, intensity...) could allow a better understanding of the real acute effect of stretching on sports performance. The

aim of this review is to analyze the acute effect of stretching routines in the warm-up according to different stretching program parameters used for the varied research studies related to warm-up designs, stretching techniques performed and stretching load.

KEY WORDS: stretching, warm-up, acute effect, sports performance

RESUMEN

Son numerosos los autores que han analizado el efecto agudo de diferentes rutinas de estiramiento dentro del calentamiento sobre el rendimiento deportivo, siendo a menudo contradictorios los resultados obtenidos. Es posible que estos resultados conflictivos puedan ser explicados por el diseño diferente de las rutinas de estiramiento, así como por la propia metodología de los estudios. Por tanto, el análisis de los diferentes componentes de la carga de una rutina de estiramientos podría permitir una mejor comprensión del efecto agudo real del estiramiento sobre el rendimiento. Con esta revisión sistemática, se pretende analizar el efecto agudo del estiramiento en función de diferentes variables metodológicas utilizadas en los estudios de investigación relacionadas con la estructuración del proceso del calentamiento, las técnicas de estiramiento utilizadas y los parámetros de la carga.

PALABRAS CLAVE: estiramientos, calentamiento, efecto agudo, rendimiento deportivo

1. INTRODUCTION

Traditionally, physical trainers, athletes and physically active people have performed long warm-up procedures and stretching routines as a part of their preparations before facing training sessions or competitions, believing that it would improve their sports performance (Fletcher & Anness 2007). However, and despite the worldwide practice of stretching exercises as an important part of the warm-up, there is limited scientific information which supports its benefits in the sports performance.

In this sense, the current scientific findings regarding the acute effect of stretching exercises in the warm-up previous to a sport activity show contradictory results. Thus, certain studies inform about the positive effects it has, while others support that stretching routines seem to have little positive effect or even negative effect on sports performance (Rubini, Costa & Gómez, 2007).

These opposing results may be explained according to the different designs of stretching routines as well as the different methods that studies have followed. Therefore, the analysis of the different stretching program parameters could allow a better understanding of the real acute effect of stretching on sports

performance. Understanding this is vital for trainers, athletes and other professionals of the field of Sport Science since it would allow a scientifically justified design of their stretching routines in order to promote positive effects on sports performance.

Hence, this systematic review aims to analyze the acute effect of stretching exercises in the warm-up according to different methodological variables used in the scientific literature: (1) Duration of stretching routines; (2) Stretching techniques; (3) Stretching intensity; (4) Structuring the warm-up procedure and (5) Study sample.

2. BIBLIOGRAPHIC SEARCH METHOD

The search of articles was made within the two online databases most important in the Health and Sport Sciences fields:

- PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>): database of the US National Library of Medicine and the National Institute of Health.
- SportsDiscus (<http://www.sirc.ca/products/sportsdiscus.cfm>): database of the Sport Information Resource Centre (SIRC) created by the Coaching Association of Canada

The key words used as a searching criterion were the following: stretching, warm-up, acute effect, strength, sports performance. There was no limitation regarding the year of publication of the studies.

3. DESIGNING STRETCHING ROUTINES

3.1. Duration of stretching routines

Studies about the acute effect of static stretching in the warm-up on sports performance during maximum force and power exercises have used different stretching volumes between 15-30 seconds (Little & Williams, 2006; Kay & Blazevich, 2008; Vetter, 2007; Yamaguchi, Ishii, Yamanaka & Yasuda, 2005) and 3600 second per muscle group (Avela, Kyrolainen & Komi, 1999, Avela, Finni, Liikavainio, Niemela & Komi, 2004).

Several studies, with a total duration of the static stretching stimulus between 90 and 3600 seconds per muscle group show a significant drop of the performance during strength exercises (table 1). In addition, these studies show force deficits between 2-3% (Bacurau, Monteiro, Ugrinowitsch, Tricoli, Cabral & Aoki, 2009; Cramer, Housh, Jonson, Millar, Coburn & Beck, 2004; Marek et al., 2005) and 28% (Avela, Kyrolainen & Komi, 1999; Fowles, Sale & MacDougall, 2000).

Along this line, Fowles, Sale and MacDougall (2000) analyzed the maximum voluntary isometric contraction (MVC) after 30 minutes of plantar flexor stretches and observed a decrease of 28% immediately after static stretching routines. Furthermore, Avela et al. (2004) reported a drop of 13.8% of isometric MVC after applying 60 minutes of static stretching of the triceps surae. In addition, Cramer et al. (2007a) obtained a reduction of about 5% of the concentric MVC of knee extension after 480 seconds of quadriceps stretches.

On the other hand, certain authors do not report a decrease on the performance after static stretching routines between 15 seconds (Kay & Blazevich, 2008) and 480 seconds (Cramer, Housh, Coburn, Beck & Johnson, 2006; Cramer, Housh, Johnson, Weir, Beck & Coburn, 2007).

Power, Behm, Cahill, Carroll and Young (2004) analyzed the acute effect of static stretching routines of 135 seconds (3x45s) per muscle group on the vertical jump height and they did not find a reduction of sports performance as a consequence of the stretches. Later on, Vetter (2007) applied a stretching routine of 30 seconds per muscle group and did not observe either a decrease of the performance during 30 meters sprints.

During the last few years the number of studies which try to analyze the importance of the total volume of static stretches in the warm-up for the performance has increased (Costa, Graves, Whitehurst & Jacobs, 2009; Kay & Blazevich, 2008; Ogura, Miyahara, Naito, Katamoto & Auki, 2007; Young, Elias & Power, 2006; Zakas, Doganis, Galazoulas & Vamvakoudis, 2006a; Zakas, Galazoulas, Doganis & Zakas, 2006b). Most of these studies suggest that high volumes of static stretching during about 2 minutes per muscle group may have an effect on the performance in force and power exercises, while low volumes seem not to (table 1).

Table 1: Acute effect of stretching duration on the performance

Reference Population	Stretching routines	Test	Performance
Young et al. (2006) M (n = 12) W (n = 8) Young adults	Static (1 exercise) a) 2x30s b) 4x30s c) 8x30s	Drop Jump	a) No changes b) No changes c) ↓ Performance
Zakas et al. (2006a) M (n = 15) Elite football players	Static a) 4 x 15s (unassisted) b) 32 x 15s (4 unassisted and 28 assisted)	Iso Con	a) No changes b) ↓ Performance
Zakas et al. (2006b) M (n = 16) Adolescent football players	Static a) 3 x 15s (unassisted) b) 20 x 15s (3 unassisted, 17 assisted)	Iso Con	a) No changes b) ↓ Performance
Ogura et al. (2007) M (n = 10) Amateur football players	Static a) 1 x 30s b) 1 x 60s	MVC Iso	a) No changes b) ↓ Performance
Kay et al. (2008) M (n = 4) W (n = 3) Physically active people	Static (assisted) a) 1 x 5s b) 1 x 15s c) 4 x 5s a) 4 x 15s	MVC Iso	a) No changes b) No changes c) No changes d) ↓ Performance
Costa et al. (2009) W (n = 28) Physically active people	Static (4 exercises) a) 3 x 15s b) 3 x 45s	Balance	a) ↑ Performance b) No changes

MVC: maximum voluntary contraction; M: men; W: women; s: seconds; Iso: isometric; Con: concentric

Zakas et al. (2006a) analyzed the effect of both a short (4x15s) and a long (32x15s) quadriceps static stretching protocols on knee extension concentric MVC. These authors do not report a decrease of concentric MCV after applying the short stretching protocol, while they do observe a decrease of about 6% after the long stretching protocol.

Young et al. (2006) analyzed the acute effect of three different stretching protocols (2x30, 4x30 y 8x30 seconds) of the triceps surae muscles in a drop jump. The results show that stretching routines of 60 and 120 second do not affect the height reached in the drop jump, while after the application of the 480 seconds stretching routine they obtained a decrease of 10.8% in the jump height.

Therefore, the total volume of muscle stretching is an important methodological variable which could explain the disparity of results obtained in scientific studies (Papadopoulos, Kalapotharakos, Noussios, Meliggas & Gantiraga, 2006) because it has been demonstrated that long static stretching protocols may

cause more effect on the performance than short protocols. In addition, when these scientific results are extrapolated to the field of sport training and competition, it is important that the stretching routines applied are realistic and show the training reality. In this sense, several authors suggest rejecting the use of long static stretching protocols designed by several scientific studies as a part of the warm-up for the following reasons: a) they do not show the reality of the stretching routines in the common sports warm-up (Young & Behm, 2002; Kay & Blazevich, 2008; Fletcher & Jones, 2004; Costa et al., 2009) and b) they cause a significant decrease on the performance during force and power exercises (Zakas et al., 2006a, Zakas et al., 2006b).

As far as the isolated time required for each static stretch per muscle is concerned, there are no previous studies comparing the effect of both durations of stretching isolated with the same total volume per muscle group. Only one study (Kay & Blazevich, 2008) compare the effect of two isolated stretching protocols by using a similar total volume of stimulus (1x15s and 4x5s) but not the same one, on the plantar flexor isometric MVC. The results obtained did not show a difference between both isolated protocols. This result could suggest that the most important thing is the total duration of the stretching stimulus, although this hypothesis is purely theoretic and it needs a better scientific support.

It is important to highlight the fact that most authors use isolated stretching protocols by series of 15 or 30 seconds and hardly any apply higher protocols (Ogura et al., 2007; Allison, Bailey & Folland, 2008). The reason of using protocols of 15 or 30 second per each stretching series is the fact that the effect of both long and short protocols on the range of motion (ROM) is exactly the same (Bandy & Irion, 1994; Bandy, Irion & Briggler, 1998; Cipriani, Abel & Pirwitz, 2003). In this sense, Ogura et al. (2007) compared the use of two different short stretching protocols, 1x30 and 1x60 seconds, in the knee flexor isometric MVC and found a significant decrease in the performance during this exercise after applying a stretching routine of 1x60 seconds. Therefore, we can add to the previous reason the hypothesis that high protocols may affect the sports performance.

More studies which analyze the best protocol of the total volume of static stretching per muscle group, as well as the most suitable one are needed. Therefore, all above mentioned hypothesis must be cautiously considered when extrapolating them to the physical and sports field.

As far as dynamic and ballistic stretch technique are concerned, it seems that there is no dependent relationship with the total volume of stretching, although this hypothesis is purely theoretic, since there are very few studies which use these stretching techniques.

Those studies which designed dynamic and ballistic stretching routines used volumes between 8 (Vetter, 2007) and 220 (Bacurau et al., 2009) repetitions per

muscle group, with a rhythm of 1 or 2 cycles per second, and the results were not very different. In this sense, Unick, Kieffer, Cheesman and Feeney (2005) did not observe modifications in the counter movement jump height after applying a ballistic stretching routine with a volume of 45 cycles per muscle group in basketball players. Thus, Bacurau et al. (2009) after applying 220 cycles of ballistic stretching on the hamstring and the quadriceps muscles did not find any effect on the maximum force.

On the other hand, there are no scientific studies (as far as we know) which analyze and compare different volumes of dynamic and ballistic stretching. As a result, scientific studies are needed to analyze which total volume of dynamic and ballistic stretching is the most effective and efficient for sportsmen as part of their warm-up.

3.2. Stretching techniques

There are a lot of stretching techniques, including static, dynamic, ballistic and proprioceptive neuromuscular facilitation (PNF) stretching techniques. In the Sports field, stretching techniques commonly used were static, dynamic and ballistic stretching (Mahieu et al., 2007). In addition, static stretching routines are generally prescribed by professionals of the Physical Activity field within the warm-up. This stretching technique has been recommended mainly because it implies a minimum injury risk, it is efficient, it requires small assistance and it is effective to increase the range of motion (ROM) (Janot, Dalleck & Reymont, 2007).

Most of the scientific studies which analyze the acute effect of stretching on sports performance use, due to its huge popularity, the static stretching technique in their warm-up (Avela Kyrolainen, H. & Komi, 1999; Avela et al., 2004; Behm et al., 2006; Brandenburg, Pitney, Luebbbers, Veera & Czajka, 2007; Cramer et al., 2004; Fowles, Sale & MacDougall, 2000; Kokkonen, Nelson & Cornwell, 1998; Maissetti, Sastre, Lecompte & Portero, 2007; Wallmann, Mercer & McWhorter, 2005; Young, Elias & Power, 2006), while only a few studies use PNF stretching techniques (Bradley, Olsen & Portas, 2007; Marek et al., 2005), dynamic (Faigenbaum et al., 2006; Little & Williams, 2006; McMillian, Moore, Hatler & Taylor, 2006; Vetter, 2007; Yamaguchi et al., 2005) and ballistic (Bacurau et al., 2009; Unick et al., 2005).

Table 2: Acute effect of stretching techniques on sports performance

Reference Population	Stretching routines	Test	Performance
Fletcher et al. (2004) W (n = 97) Rugby players	7 exercises a) Static: 1 x 20s b) Dynamic: 1 x 20 rep	20m sprint	a) ↓ Performance b) ↑ Performance
Marek et al. (2005) M (n = 9) W (n = 10) Physically active people	4 exercises (1 unassisted, 3 assisted) a) Static: 4 x 30s a) PNF: 4 x 30s	Iso Con	a) ↓ Performance b) ↓ Performance
Papadopoulos et al. (2005) M (n = 8) Physically active people	2 exercises (unassisted) a) Static: 3 x 30s b) Dynamic: 6 x 15rep	Iso Con	a) ↓ Performance b) No changes
Unick et al. (2005) W (n = 16) Basketball players	4 exercises a) Static: 3 x 15s b) Ballistic: 3 x 15 rep	CMJ Drop Jump	a) No changes b) No changes
Faigenbaum et al. (2006) M (n = 36) W (n = 4) Adolescents	a) Static: 5 exercises (2 x 30s) b) Dynamic: 9 exercises (2 x 10 yards)	Medicine ball launch 10 yards sprint Agility circuit	a) ↓ Performance b) ↑ Performance
Little et al. (2006) W (n = 28) Professional football players	5 exercises a) Static: 1 x 30s b) Dynamic: 1 x 30 rep	10m sprint 20m sprint Zig-zag circuit	a) ↓ Performance 20 m sprint b) ↑ Performance
McMillian et al. (2006) M (n = 16) W (n = 14) Soldiers	a) Static: 8 exercises (1 x 20-30s) b) Dynamic: 16 exercises (1 x 10 rep)	Medicine ball launch Long jump Agility circuit	a) No changes b) ↑ Performance
Bradley et al. (2007) M (n = 18) Students	5 exercises a) Static: 4 x 30s b) PNF: 4 x 30s	Squat jump CMJ	a) ↓ Performance b) ↓ Performance
Vetter et al. (2007) M (n = 14) W (n = 12) Physically active people	5 exercises a) Static: 1 x 30s a) Dynamic: 1 x 8 rep	30 m sprint	a) No changes b) No changes
Bacurau et al. (2009) W (n = 14) Physically active people	6 exercises a) Static: 3 x 30s a) Ballistic: 3 x 30 rep	1 RM	b) ↓ Performance c) No changes
Ayala et al. (2010) M (n = 28) Adolescent football players	2 exercises a) Static: 1 x 30s a) Dynamic: 1 x 15 rep	10m sprint 30m sprint	a) ↓ Performance b) No changes

MVC: maximum voluntary contraction; M: men; W: women; s: seconds; Iso: isometric; Con: concentric

Studies which use static stretching routines in the warm-up previous to a sports activity show contradictory results (table 2). On the one hand, there are a great amount of studies which demonstrate negative acute effect on muscle maximum force and power (Avela et al., 2004; Behm et al., 2006; Cornwell, Nelson & Sidaway, 2002; Cramer et al., 2004; Cramer et al., 2007a; Evetovich, Nauman, Conley & Todd, 2003; Kokkonen, Nelson & Cornwell, 1998; Fowles, Sale & MacDougall, 2000; Nelson & Kokkonen, 2001; Wallmann, Mercer &

McWhorter, 2005). However, on the other hand, certain authors do not find any impact from static stretching on sports performance (Brandenburg, Pitney, Luebbers, Veera & Czajka, 2007; Costa et al., 2009; Cramer et al., 2006; Egan, Cramer, Massey & Marek, 2006; Papadopoulos et al., 2006; Power et al., 2004). This discrepancy may be due to variables such as the total volume of stretching (previously analyzed), the kind of test used and the structure of the warm-up. There is a big gap regarding the comparison between static-passive stretching and static-active stretching. Only Ayala and Sainz de Baranda (2010) compared both stretching techniques with the same duration of the tensional stimulus on the hamstring (180 seconds). These authors observed that static-passive stretching caused significant decreases on sports performance during the 30 meters sprint, while static-active stretching did not affect significantly the time the football players from the youth team Honor Division spent to go over the 30 meters.

The scientific literature that studies the impact of PNF stretching on sports performance is limited (Bradley, Olsen & Portas, 2007; Marek et al., 2005; Young & Elliott, 2001). Marek et al. (2005) studied the acute effect of PNF stretching on concentric MVC. The subjects developed four PNF stretching exercises for quadriceps previous to the evaluation process. The results showed a significant decrease of the knee extension MVC as a consequence of stretching. Another study compared the effect of two different stretching protocols on the explosive force and performance of a vertical jump (Young & Elliott, 2001). The stretching consisted on 5 minutes running followed by a static stretching routine or PNF stretching or rest (group control). Researchers did not find differences on sports performance of the vertical jump after the different stretching protocols.

In addition, in the last few years the scientific interest on analyzing the impact of dynamic and ballistic stretching routines as a part of the warm-up on sports performance due to the possible negative acute effect of static stretching has increased. Therefore, studies which analyze and compare different stretching techniques within the same warming-up protocol are already scarce and very recent (Ayala & Sainz de Baranda, 2009; Bacurau et al., 2009; Faigenbaum et al., 2006; Little & Williams, 2006; McMillian et al., 2006; Thompson, Kackley, Palumbo & Faigenbaum, 2007; Unick et al., 2005; Vetter, 2007).

Ayala and Sainz de Baranda (2010) compared the effect of static and dynamic stretching routines with similar volumes (2x30s and 2x15s repetitions respectively) on sports performance during the stationary and the flying 10 and 30 meters sprint and they observed that the static technique caused a negative effect on performance while the dynamic technique did not affect it. In the same way, Flecher and Jones (2004) reported that when comparing a static stretching with a dynamic technique as a part of the warm-up previous to a 20m sprint, the performance in the 20m was negatively affected after the static stretching, while after the dynamic stretching the time spent to finish the 20m sprint dropped 1.85%. The results obtained by Vetter (2007) showed a decrease in the vertical

jump height after static stretching, while the performance in the jump increased after dynamic stretching routines.

Therefore, the results of different scientific studies which compare stretching routines with different techniques and the same volume suggest that dynamic and ballistic techniques present, in many cases, a positive effect on sports performance, while static and PNF stretching techniques present contradictory results between a negative effect and no impact at all on performance.

3.3. Stretching intensity

Stretching intensity is another important variable when designing warm-up routines that could improve performance (Young, 2007). This concept refers to the “distance” reached in the muscle elongation as a consequence of a stretching exercise (Young et al., 2006).

The study of stretching intensity is limited since the only technique analysed is the static one (Gajdosik, Lentz, McFarley, Meyer & Riggin, 2006; Young et al., 2006).

The suitable method to measure the static stretching exercises' intensity has been scarcely described in the scientific literature (Young et al., 2006; Young, 2007). Stretching intensity has generally been established through instructions related to subjective perceptions of the participants regarding their feeling of stretching such as the following: “perceived pain” (Nelson & Kokkonen, 2001), “pain threshold” (Kokkonen, Nelson & Cornwell, 1998), “point of mild discomfort” (Cramer et al., 2004; Cramer et al., 2006; Cramer et al., 2007; Egan et al., 2006), “point just before discomfort occurs” (Ogura et al., 2007; Unick et al., 2005; Wallmann et al., 2005).

Young et al. (2006) reported a possible tendency to avoid effects on muscle power after applying a stretching treatment with 90% of intensity (measured through the maximum ROM in a joint) rather than another stretching routine with 100% of intensity (maximum tolerated sensation). In addition, Gajdosik et al. (2006), after analyzing 3 different static stretching intensities (100%, 90% and 80% of maximum ROM), observed that with the same duration (60s) there were no differences in the effect on passive and dynamic elastic properties.

Therefore, it is possible that static stretching intensity is another important variable that may affect the posterior muscle performance, although since the scientific literature regarding this topic is limited, this theory is purely theoretic and it must be considered cautiously.

3.4. Structuring the warm-up process and its impact in performance

In order to apply the scientific results related to the use of stretching exercises in the warm-up previous to training sessions and competitions present in the

literature it is important that not only the used stretching routines are realistic and contextualized with the stretching program parameters, but also that the structure of the warm-up reflects a sports reality.

In this sense, a stretching routine often includes: a) a general part regarding activities such as running or cycling at sub-maximum intensities (general warm-up); a series of stretching exercises, usually static (stretching routine); and c) a specific part with activities related to actions proper of the sport they will play afterwards (specific warm-up) (Young & Power, 2006; Young, 2007).

Despite the popularity and acceptance of this warming-up structure, studies which analyze the acute effect of stretching routines as part of the warm-up of a sport use different methodological designs. These designs are obtained from the substitution and/or different distribution of one or several parts of a traditional warming-up routine.

On the one hand, a great number of studies (Brandenburg et al., 2007; Behm et al., 2006; Cramer et al., 2004; Cramer et al., 2007a; Cramer et al., 2007b; Egan et al., 2006; Fletcher & Jones 2004; Kay & Blazevich, 2008; Marek et al., 2005; Papadopoulos et al., 2006; Thompsen et al., 2007; Unick et al., 2005; Wallmann et al., 2005; Young et al., 2006; Young et al., 2006; Zakas et al., 2006a; Zakas et al., 2006b) use as experimental design the following one:

General warm-up + Stretching exercises routine

Those studies tried to evaluate the effect of different combinations of general warm-up with and without stretching routines. In addition, the general warm-up phase was mainly formed with aerobic exercises at sub-maximum intensity in cycleergometer (Brandenburg et al., 2007; Behm et al., 2006; Cramer et al., 2004; Cramer et al., 2007a; Cramer et al., 2007b; Costa et al., 2009; Egan et al., 2006; Marek et al., 2005; Papadopoulos, Siatras, & Kellis, 2005; Thompsen et al., 2007; Unick et al., 2005; Wallmann et al., 2005; Young et al., 2006; Young et al., 2006; Zakas et al., 2006a; Zakas et al., 2006b) or with running (Bacurau et al., 2009; Fletcher & Jones 2004; Kay & Blazevich, 2008; Papadopoulos et al., 2006;; Young et al., 2006).

However, although this research design allow the evaluation of the effect isolated from stretching routines, it does not reflect the structure of the warm-ups sportsmen do, since stretching routines are placed at the end of the warm-up (Young, 2007). Furthermore, this warming-up structure do not consider the influence of specific warm-ups on the performance of the sport below.

Along this line, most of the studies about the effect of general warm-up with and without stretching exercises (Allison et al. 2008; Bacurau et al. 2009; Cornwell, Nelson, & Sidaway, 2002; Young et al., 2006; Zakas et al., 2006a; Zakas et al., 2006b), but not all of them (Papadopoulos, Siatras, & Kellis, 2005; Unick et al., 2005) reported that the combination of general warm-up with a stretching

routine reached significantly better increases of ROM than the isolated general warm-up independently of the type stretching routine used and the mean used for the aerobic exercises (bicycle ergometer or running). In addition, the results of the muscle force and power parameters seem to depend on the design chosen for the stretching routine.

On the other hand, Young (2007) suggests that in order to analyze the acute effect of stretching routines within the sports warm-up context, the ideal research design would be comparing both protocols: a) general warm-up + stretching routine + specific warm-up (traditional warm-up); with b) general warm-up + specific warm-up.

This research design could give an answer to the question regarding to whether including stretching exercises routines within warm-ups affect significantly the performance compared to warming-up protocols without stretching routines (Young, 2007).

However, there are very few studies which use this kind of research designs (Fletcher & Anness 2007; Little & Williams, 2006; Vetter, 2007; Young, Clothier, Otago, Bruce & Liddell, 2004).

Young et al. (2004) investigated the influence of static stretching routines on the speed of kicking the ball with Australian Football players. One of the warm-ups consisted on 5 minutes running, static stretching exercises and 7 launches at increasing intensity (specific warm-up). This protocol was compared to another one with running and kicking. The stretching routine had a volume of 90s (3x30s) stretching per muscle group. The results showed that there were no differences on kicking speed between both warming-up protocols.

Little & Williams (2006) also developed a warm-up consisting on: 4 minutes running + stretching routine (static or dynamic) + short sprints with changes of direction, and they compare it to another warm-up without stretching routine which acted as control, both of them with professional football players and using a crossover design. After each warm-up, the football players were assessed in the vertical jump, the sprint and the agility circle. These results showed that warming-up protocols with stretching routines (static and dynamic) obtained better performance values in the 20-meter sprint test than the warming-up protocol without stretching exercises. In addition, the warm-up which used the dynamic stretching technique obtained the best results for acceleration capacity.

Vetter (2007) compared the effect of 6 different warm-ups on the performance during a counter jump and a 30-meter sprint. The analyzed warming-up protocols were the following: a) general warm-up; b) general warm-up + specific warm-up; c) general warm-up + dynamic stretching routine + specific warm-up; d) general warm-up + dynamic stretching routine; e) general warm-up + static stretching routine + specific warm-up; f) general warm-up + static stretching

routine. A significant jump's height decrease was observed after the warming-up protocol consisting on general warm-up + static stretching routine. The protocol consisting on general warm-up + dynamic stretching routine + specific warm-up obtained a significant increase of the performance in the vertical jump compared to the other protocols.

Therefore, these studies suggest that to do a stretching routine with a contextualized volume after aerobic exercises at sub-maximum intensity and before sports exercises at high intensity could not affect or it could even improve performance. This statement contradicts the results obtained by the studies which used protocols consisting on general warm-up + static stretching routine. A possible explanation may be the fact that the negative acute effect on force performance attributed to static stretching routines may be affected by the specific phase of the used warming-up protocol.

3.5. Study sample

There are very few studies which analyze the acute effect of a stretching routine depending on sex; we find that both men and women have the same response for a particular stretching acute load (Cramer et al., 2007; Fletcher & Anness 2007; Vetter, 2007).

Furthermore, the acute effect does not depend on the kind of population studied, since it seems to have the same effect on athletes (Ogura et al. 2007; Zakas et al., 2006a; Zakas et al., 2006b), physically active subjects (Cramer et al., 2007a; Evetovich et al., 2003; Fowles, Sale & MacDougall, 2000; Yamaguchi et al., 2006) and sedentary people (Avela, Kyrolainen & Komi, 1999; Avela et al., 2004). However, it seems to be a tendency with which athletes could present lower susceptibility to the static stretching negative acute effect.

This hypothesis may be supported by the results obtained by Egan et al. (2006) and Marek et al. (2005), since when applying the same stretching routine to two different populations (high level basketball players and physically active people respectively), they did not find in the former a negative acute effect on the concentric isokinetic MVC at 60° and 300°/s, while the latter observed a significant force reduction at both speeds.

However, this hypothesis is purely theoretic, since there are not studies which compare specifically the acute effect of a stretching routine with the same load parameters in different populations: sportsmen, physically active people, sedentary people, etc.

Another important aspect is found in the studies of Little & Williams (2006) and Fletcher & Jones (2004), since both studies applied similar static stretching routines to professional football players and amateur rugby players. They did not find any time reduction with the former's sprint, but they observed a performance decrease in the latter. On the other hand, Knudson, Noffal,

Bahamonde, Bauer & Blackwell (2004) used for their studies tennis players from different levels, ages and sex and they observed that there is a consistent influence from the stretching among these variable. Each sports modality can make specific adaptations for its players independently of the sex, level and age, which may influence stretching routines effects.

4. CONCLUSIONS

In the last few years, many scientific studies have evaluated the acute effect of different stretching routines on sports performance in muscle force and power tests (tables 1 and 2). In addition, the methodological designs, stretching routines, study samples and instructions followed have presented an enormous variability between all these studies which could explain the diverse obtained results.

A simplistic view of the scientific literature could establish as a conclusion that static and PNF stretching routines present a negative acute effect on performance in muscle force and power tests, while dynamic stretching routines may present a positive tendency towards a performance improvement. These considerations would suppose the remove of static stretching routines in every warm-up previous to a physical and sports activity.

However, an analysis in depth of these studies reveals that most of them use static stretching routines with a decontextualized load from the sports field and more appropriate of the clinical field. On the other hand, most of them are laboratory studies, with a great intern validity but little ecologic validity, where the different assessment tools do not reflect proper actions of the competitive field but isolated and decontextualized actions (Murphy & Wilson, 1997). In addition, the structure of warming-up protocols used in them does not reflect the reality of the training phase of athletes.

For all these reasons, it would be a mistake to affirm that using static stretching routines in the warm-up must be removes or that it has a negative effect on performance. However, more scientific studies are needed to analyze the acute effect of static and especially dynamic stretching routines with load parameters adapted to the sport's reality by using appropriate methodological designs and selecting assessment tests which reflect real changes on sports performance.

From the sports training point of view, the critical analysis of the scientific literature made in this review is useful to obtain a positive effect on performance after appropriately using stretching exercises in the warm-up, bearing into account both the warm-up structure and the stretching techniques and load parameters, so that we conclude:

1. All warming-up programs should include stretching routines.

2. The structure used should be “general warm-up + stretching routine + specific warm-up”.
3. Regarding stretching techniques, active, dynamic and ballistic techniques are recommended.
4. When applying static stretching techniques in the warm-up they should be short (under 2 minutes per muscle). In addition, the isolated duration of each stretching is recommended to last from 5 to 15 seconds.
5. Static stretching intensity should be “slight feeling of tightness” (80-85% of the maximum joint ROM)
6. The positive effect of dynamic and ballistic techniques on sports performance may not be affected by the number of cycles or repetitions they are done, although a volume of 60 cycles per muscle group divided in series of 15-20 repetitions is recommended.

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