

Effect of Physical Education-based stretching programs on hamstring extensibility in high school students: A systematic review

Efecto de los programas de estiramiento en Educación Física sobre la extensibilidad de la musculatura isquiosural en estudiantes de Educación Secundaria: Una revisión sistemática

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Abstract

The purpose of the present review was to examine the effects of Physical Education-based stretching programs on hamstring extensibility in high school students. Relevant studies were searched from 10 databases. The results suggested that students should performed stretching programs at least for a duration of 5-6 weeks, a frequency of twice a week, and a volume per session of 30-60 s (20-30 s per set) to obtain improvements on the hamstring extensibility. Stretching programs with higher duration, frequency and volume seems to obtain greater effects. Although the most studies obtained flexibility improvements using static techniques, dynamic stretching exercises performed in a controlled manner also produced improvements and they were safety. After a four-week detraining period, students reverted back to their baseline levels. Teachers should implement stretching programs to improve the students' flexibility during the Physical Education classes.

Key words: Hamstring muscles extensibility, range of motion, flexibility program, secondary school, adolescents.

Resumen

El objetivo de la presente revisión fue examinar los efectos de los programas de estiramiento en Educación Física sobre la extensibilidad de la musculatura isquiosural en estudiantes de Educación Secundaria. Los estudios relevantes se buscaron en 10 bases de datos. Los resultados sugirieron que los estudiantes deberían realizar programas de estiramientos con al menos una duración de 5-6 semanas, una frecuencia de dos veces por semana, y un volumen por sesión de 30-60 s (20-30 s por serie) para obtener mejoras en la extensibilidad de la musculatura isquiosural. Programas de estiramientos con una mayor duración, frecuencia y volumen parecen obtener mayores efectos. Aunque la mayoría de los estudios obtuvieron mejoras de la flexibilidad usando técnicas estáticas, los ejercicios dinámicos realizados de forma controlada también produjeron mejoras y fueron seguros. Después de un período de desentrenamiento de cuatro semanas, los estudiantes volvieron a sus niveles basales. Los profesores deberían implementar programas de estiramiento para mejorar la flexibilidad de los estudiantes durante las clases de Educación Física.

Palabras clave: Extensibilidad de la musculatura isquiosural, rango de movimiento, programa de flexibilidad, Educación Secundaria Obligatoria, adolescentes.

Introduction

Nowadays physical fitness is considered one of the most important health markers in adolescence (Ortega, Ruiz, Castillo & Sjöström, 2008), where flexibility (i.e., the physical fitness component characterized as the skill to execute movements with a wide range of motion, Merino Marban, López Fernández, Torres Luque & Fernández Rodríguez, 2011) is an essential component of health-related physical fitness (National Association for Sports and Physical Education, 2005). Particularly, low hamstring extensibility (i.e., the property of the body tissues for lengthening or extending due to stretching, which in part, it conditions the individual's flexibility, Merino Marban & Fernández Rodríguez, 2009; Merino Marban et al., 2011) has been associated with several spinal disorders such as thoracic hyperkyphosis (Fisk, Baigent, & Hill, 1984), spondylolysis (Standaert & Herring, 2000), disc herniation (Harvey & Tanner, 1991), changes in lumbopelvic rhythm (López-Miñarro & Alacid, 2009) and low back pain (Sjölie, 2004). Moreover, adolescents with an inadequate hamstring extensibility seem to have a higher risk of current low back pain (Feldman, Shrier, Rossignol, & Abenhaim, 2001; Jones, Stratton, Reilly & Unnithan, 2005; Sjölie, 2004) and neck tension (Mikkelsen et al., 2006), as well as a higher risk of low back pain later during adulthood (Hestbaek, Leboeuf-Yde, Kyvik, & Manniche, 2006; Kujala, Taimela, Salminen & Oksanen, 1994).

Unfortunately, flexibility is characterized to be in a permanent involution process (Chodzko-Zajko et al., 2009). Actually, many investigations have revealed muscle shortening even in school age children, especially in the hamstrings (Brodersen, Pedersen & Reimers, 1994; Harreby et al., 1999; Kanasova, 2008; Rodríguez, Santonja, López-Miñarro, Sainz de Baranda & Yuste, 2008; Santonja, Sainz de Baranda & Rodríguez, 2007; Vidal, Almiñana, Zamorano & Almiñana, 2011). For instance, in Spain over one in five adolescents have limited hamstring extensibility (Castro-Piñero et al., 2013; Ortega et al., 2005). For this reason, it is essential applying programs that pursue flexibility development and maintenance during adolescence (Borras et al., 2007; Kanasova, 2008; Sainz de Baranda, 2009). Therefore, health promotion policies should also be designed to identify adolescents with low hamstring extensibility, as well as to encourage them to achieve health-enhancing levels (Ortega et al., 2008).

The subject of physical education (PE) might play an important role in this public health issue. Shortened hamstring muscles could be addressed proactively by systematically performing stretching exercises during PE sessions (Merino-Marban, Mayorga-Vega,

Fernández-Rodríguez, Vera Estrada, & Viciano, 2015; Rodríguez et al., 2008; Santonja Medina, Sainz de Baranda Andújar, Rodríguez García, López Miñarro & Canteras Jordana, 2007; Thacker, Gilchrist, Stroup & Kimsey, 2004; Van Rensburg & Coetzee, 2014). Since PE has the potential of optimizing environmental conditions and giving prolonged feedback that reaches a large percentage of the population, Rodríguez et al. (2008) suggest that the PE class must be an ideal setting for hamstring shortness prevention. Additionally, the high prevalence of sagittal spinal misalignments makes necessary to include stretching exercises for the hamstring stretches in PE classes (Santonja, Rodríguez, Sainz de Baranda & López Miñarro, 2004). On the other hand, due to the brief nature of this kind of interventions stretching exercises do not interfere with the planning of other class content within flexibility programs (Coledam et al., 2012).

Several previous studies have shown that a PE-based static stretching program improves students' hamstring extensibility in both primary (Mayorga-Vega, Merino-Marban, Vera-Estrada & Viciano, 2014b; Merino-Marban et al., 2015; Sánchez Rivas, Mayorga-Vega, Fernández-Rodríguez & Merino-Marban, 2014) and high school students (Becerra-Fernández, Merino-Marban & Mayorga-Vega, 2016; Mayorga-Vega, Merino-Marban, Real & Viciano, 2015; Sainz de Baranda, 2009; Van Resbourg & Coetzee, 2014). There are also some previous studies that have examined the effectiveness and safety of a dynamic stretching program in high school students (Becerra-Fernández et al., 2016; Van Rensburg & Coetzee, 2014; Vidal, 1995). Recently, Becerra-Fernández and Merino-Marban (2015) performed a systematic review of the effect of PE-based stretching programs on hamstring extensibility in primary schoolchildren. Unfortunately, to our knowledge there is not any systematic review about the efficacy of hamstring stretching programs in high school students. Consequently, the main purpose of the present review was to examine the scientific literature on the effects of physical education-based stretching programs on hamstring extensibility in high school students aged 12-17 years

Method

Data sources and search strategy

The following 10 electronic databases were searched from their inception through January 2016: Sport-Discus, Web of Science, Scopus, ASSIA, CINAHL, Cochrane, IBSS, Proquest Dissertation and Theses, Proquest Education Journals, and ERIC. The search-

es were carried out in the search field type “Title, abstract, and keywords” or equivalent. The search terms used were based on four concepts: (1) flexibility, (2) intervention, (3) hamstring extensibility test, and (4) population/PE setting. The terms of the same concept were combined together with the Boolean operator “OR” and then the four concepts were combined using the Boolean operator “AND”. The truncated root of certain terms was followed by an asterisk to include multiple variants. The keywords that consisted of more than one word were enclosed in quotes.

The specific search syntax used in the present review was the following: (flexibility OR elasticity OR extensibility OR ROM OR “range of motion” OR “range of movement” OR stretch*) AND (training OR detraining OR program* OR intervention OR exercise*) AND (“straight leg raise” OR “straight-leg raise” OR “knee extension” OR “popliteal angle” OR “sit-and-reach” OR “sit and reach” OR “toe-touch” OR “toe touch” OR “stand-and-reach” OR “stand and reach” OR “finger to floor distance” OR “fingertip floor distance” OR “forward bend” OR “angular test*” OR “lineal test*” OR hip* OR hamstring) AND (child* OR kid* OR adolescent* OR teenager* OR youth OR young OR pubertal OR pubescent* OR prepubertal OR prepubescent* OR preadolescent* OR boy* OR girl* OR schoolchild* OR student* OR pupil* OR education OR school OR “physical education” OR PE).

As a result of the selected studies from the Boolean-based database search, additional records were identified through other sources: (1) searching the reference lists of included studies and some related study reviews; (2) examining the reference citations in the Web of Science and Scopus databases; (3) searching the researchers’ publications (first authors) in the Web of Science, Scopus and SportDiscus databases; (4) contacting by email with the corresponding authors (if they were not defined, the first author was used), and (5) screening the researchers’ personal lists in ResearchGate and Google Scholar (first authors). No publication format, language or date restrictions were imposed. For practical reasons, the search, study selection and data collection were carried out for one researcher (CABF).

Study selection

The selection criteria to identify studies that examined the hamstrings stretching programs on flexibility improvement in high school students were the following: (a) studies with apparently healthy participants who did not present any injury, physical and/or mental disabilities; (b) studies that assess the hamstring extensibility before and after the stretching program with tests widely accepted in the scientific literature

(e.g., straight leg raise or knee extension tests, classic or modified sit-and-reach test); (c) studies in which participants’ age ranged from 12-17 years; (d) studies which included control group, (e) and intervention programs were focused on hamstring stretching exercises.

Data collection

From each selected study the following data were extracted: Reference, sample size (n), sex of participants, age of participants, duration of the program, frequency of the program, stretching volume, stretching intensity, stretching exercises, test protocols and results. Because identification of study features was usually explicitly stated in each of the primary articles, the use of more than one rather was deemed unnecessary. Based on Borenstein, Hedges, Higgins, and Rothstein (2009), the unstandardized mean difference [$D = (\text{Mean}_{\text{Post-intervention experimental}} - \text{Mean}_{\text{Pre-intervention experimental}}) - (\text{Mean}_{\text{Post-intervention control}} - \text{Mean}_{\text{Pre-intervention experimental}})$] and standardized mean difference ($d = D / SD_{\text{Pre-intervention pooled}}$) were calculated. Based on the Cohen’s (1992) benchmarks, effect sizes were interpreted as very low ($d = 0.00-0.19$), low ($d = 0.20-0.49$), moderate ($d = 0.50-0.79$) and high ($d \geq 0.80$).

Results

Figure 1 shows a flow chart of the study selection process. Of the 5,861 literature search results, 30 potentially relevant publications were identified and retrieved for a more detailed evaluation. A total of 20 studies were excluded because they did not meet the inclusion criteria, while 10 studies did. Subsequently, other modes of searching were performed and two new articles met the inclusion criteria, whereas one of them was excluded for duplicated information. Finally, 11 studies were included in the present review. The general characteristics of the studies which included hamstring stretching programs as a part of PE classes are shown in Table 1.

Discussion

Duration, frequency, volume and intensity of the development program

Regarding the duration of the program, the present systematic review found studies examining the effect of short-, middle- and long-term stretching programs. Although the results of the studies showed that the

Table 1. General characteristics of the included studies

Reference	Sample				Session part	Stretching Technique
	Gender (n)	Age (years)	Duration (weeks)	Frequency (ses/ wk)		
Becerra-Fernández et al. (2016)	♀ = 102	16-17	12	2	Warm-up/ cool-down	Dynamic Active (soft repetitive bounces)
Mayorga-Vega et al. (2015)	♂ = 94 ♀ = 86	12-14	8	EG1 = 1 EG2 = 2	Cool-down	Static active
Van Rensburg & Coetzee (2014)	♀ = 100	13-17	6	3	Warm-up	Static passive (EG1-3) Dynamic active (EG4)
Kamandulis et al. (2013)	♂ = 107 ♀ = 132	15.1	5	2	Warm-up	Static active
Uteros & Campos (2011)	♀ = 23 ♂ = 10	16-17	5	2	Warm-up	Static passive
Sainz de Baranda (2009)	♂ = 23 ♀ = 27	13.7	31	2	Warm-up/ Cool-down	Static active (warm-up) Static passive (cool-down)
Rodríguez et al. (2008)	♂ = 21 ♀ = 23	13.5	32	2	Warm-up/ Cool-down	Static active
Nelson & Bandy (2004)	♂ = 69	16.4	6	3	Warm-up	Static passive
Reid & Mcnair (2004)	♂ = 43	15.8	6	5	Warm-up	Static passive
Rodríguez et al. (1999)	♂ = 18 ♀ = 21	13.5	32	2	Warm-up/ Cool-down	Static passive
Vidal (1995) ^b	♂ = 73 ♀ = 90	16-17	6	3	Warm-up	Static/ Dynamic passive/ active

Note: ♂ = Boys; ♀ = Girls; EG = Experimental group. a - Data reported for the stretching program refers only to the hamstring muscle stretching (i.e., when stretching exercises for other muscles were performed, they were not considerate). When there were one-leg stretching exercises, volume data were reported considering the stretching load performed by each hamstring muscle. b - Since pre-intervention scores were not reported, effects sizes could not be calculated. * p < 0.05

program ^a	Exercises	Volume (per session)	Intensity	Test	Effect size (d)
	Bipodal: Sitting with feet together. Spine neutral position	8 wk: 2 x 60 s (warm-up)/ 2 x 60 s (cool-down) Total: 240 s (4 wk holidays) 4 wk: 2 x 60 s (cool-down) Total: 120s	Feeling tightness, but no pain	Classic sit-and-reach	8 wk: D = 2.5 cm d = 0.39* 8+4 wk: D = 5.4 cm d = 0.84*
	Bipodal/ unipodal Sitting/ standing with feet together/ separate/ one leg. Spine neutral position	8 x 30 s Total: 240 s	Feeling tightness, but no pain	Classic sit-and-reach	EG1: D = 1.2 cm d = 0.17* EG2: D = 1.6 cm d = 0.23*
	Unipodal Standing/ lying with one leg. Spine neutral position	EG1: 5 x 30 s (static passive) EG2: 8 x 10-10 s (PNF: contract-relax) EG3: 8 x 10-10 s (PNF: hold-relax) EG4: 10 x 30 s (active dynamic) Total: 150-300 s	Feeling tightness	Passive knee extension	EG1: D = 24.8° d = 2.18* EG2: D = 24.7° d = 2.26* EG3: D = 25.3° d = 2.41* EG4: D = 24.6° d = 2.34*
	Bipodal EG1: Classic sit-and-reach EG2: Sitting with feet together EG3: Sitting/ standing with feet together/ Sitting with feet separate. EG1-3: Spine flexion	EG1: 4 x 2 s EG2: 4 x 20 s EG3: 12 x 20 s Total: 8-240s	?	Classic sit-and-reach	EG1: D = 0.8 cm d = 0.11* EG2: D = 2.4 cm d = 0.32* EG3: D = 4.4 cm d = 0.59*
	?	3 x 15 s Total: 45 s	Moderate, no pain	Stand-and-reach Passive straight leg raise	D = 3.57 cm d = ? * D = 7.69° d = ? *
	Bipodal/ unipodal Standing with feet together/ one leg; Lying with one leg. Spine neutral position	12 x 15 s (warm-up) 6 x 15 s (cool-down) Total: 270 s	?	Passive straight leg raise	D = 9.15 cm d = 0.94*
	Bipodal Standing with feet together. Spine neutral position	9 x 20 s (warm-up) 6 x 20 s (cool-down) Total: 300 s	Feeling tightness, but no pain	Classic sit-and-reach	D = 9.53 cm d = 1.35*
	Unipodal Standing (EG2)/ lying (EG1) with one leg. Spine neutral position	EG1: 6 x 5-5 s (stretch-eccentric) EG2: 1 x 30 s Total: 30-60 s	Feeling tightness	Passive knee extension	EG1: D = 11.62° d = 1.81* EG2: D = 10.88° d = 1.64*
	Unipodal Standing with one leg. Spine neutral position	3 x 30 s Total: 90 s	Feeling tightness	Passive knee extension	D = 7.1° d = 1.04*
	Bipodal Sitting with feet separate. Spine neutral position	300 s (warm-up) 120 s (cool-down) Total: 420 s	?	Classic sit-and-reach	D = 7.6 cm d = 1.14*
	Bipodal Sitting with feet together. Spine flexion	EG1-7: EG1: static active EG2: static passive EG3: static mix EG4: dynamic active EG5: dynamic passive EG6: dynamic mix EG7: Kabat method Total: 120 s	?	Classic sit-and-reach	D = ? d = ?*

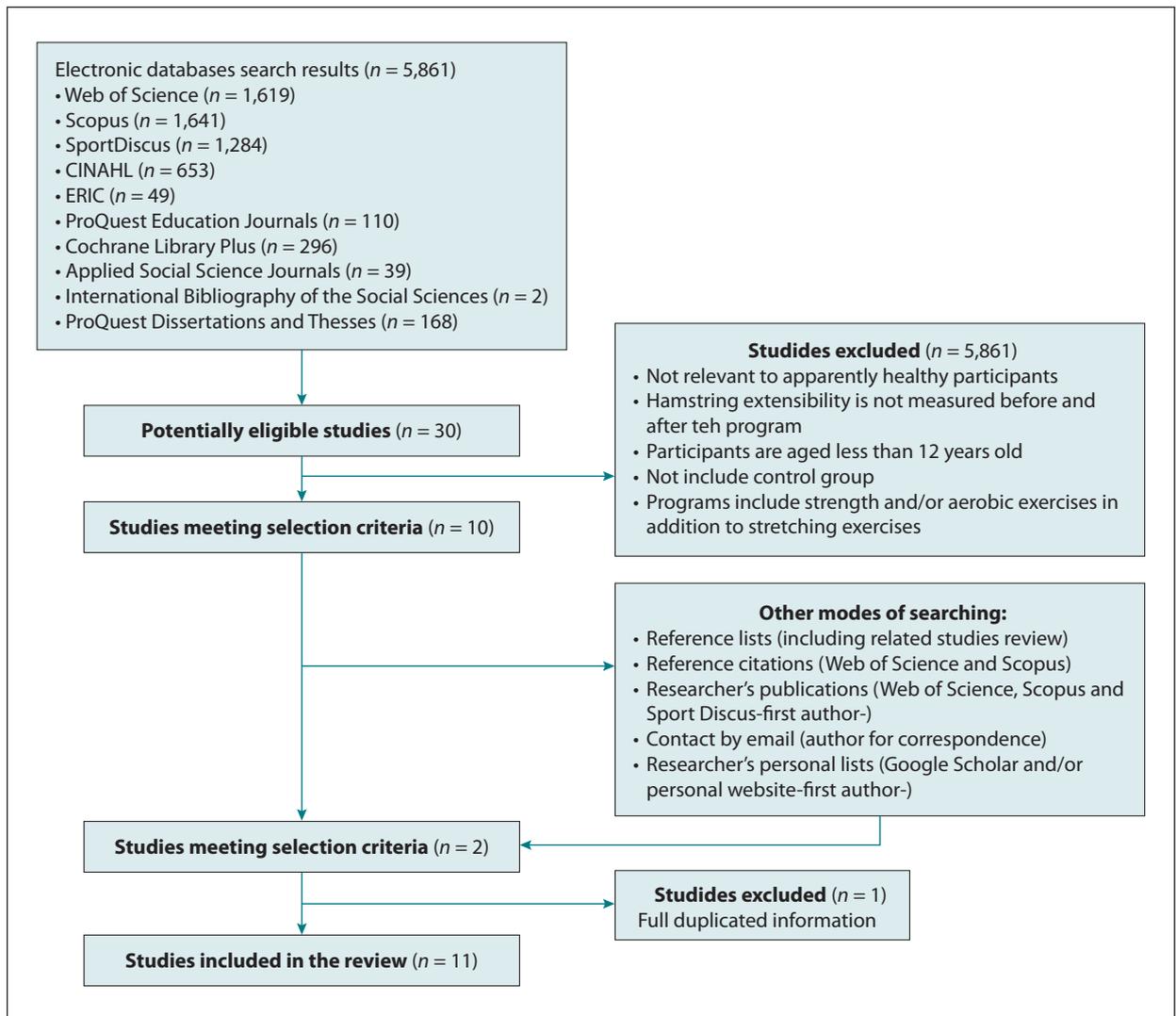


Figure 1. Flow chart of studies selection process

stretching programs for at least five weeks had a statistically significant improvement in students' hamstring extensibility levels, the effect of the stretching program trended to increase with the duration of the program (e.g., median d values for the CSR: short-term, 5-6 weeks: 0.22; middle-term, 8-12 weeks: 0.84, and long-term, 31-32 weeks: 1.24). However, since any within-study comparison was found, due to the disparity in the studies program characteristics, these conclusions should be taken with caution. Future studies that compared the effect of the duration of the program are needed.

Regarding the frequency of the program, the present systematic review found studies examining the effect of stretching programs performed from one to five times per week. The results showed that the stretching programs for at least once a week had a statistically significant improvement in students' ham-

string extensibility levels. However, the effect sizes for the program performed once a week was very low ($d = 0.17$), so at least twice a week is recommended. Mayorga-Vega et al. (2015) compared the effect of a PE-based stretching program performed once and twice a week. Although these authors found that the students of both experimental groups improved statistically significantly their hamstring extensibility compared with the control group students ($p < 0.01$), no statistically significant differences between the two experimental groups were found ($p > 0.05$). However, due to the fact that all the lineal test-based studies performed the stretching program twice a week (but Mayorga-Vega et al. 2015 that also examined once a week) and angular test-based were three and five times (except Sainz de Baranda, 2009 that examined twice a week) any trend could be explored between other frequencies. Additional studies that

compare the effect of different frequencies of the stretching program are required.

Regarding the volume of the program, the present systematic review found a high variability between studies, because there were studies examining the effect of stretching programs performed from a total volume of 8 s to 300 s per session (from 1 to 12 set, and from 2 s to 60 s per set). Although the results showed that the stretching programs for at least 8 s (4 x 2 s) had a statistically significant improvement in students' hamstring extensibility levels, the magnitude effect was very low ($d = 0.11$). Thus, a total volume per session of at least 30-60 s seems to be recommended. Kamandulis et al. (2013) compared the effect of a stretching program performed with a volume per session of 4 x 2 s (8 s), 4 x 20 s (80 s) and 12 x 20 s (240 s). Although these authors found that the three groups found statistically significant improvement of hamstring extensibility, the students that performed a total of 240 s per session increased more than those who performed 80 s and 8 s.

Regarding the intensity of the program, the present systematic review found that in all the studies were defined by the stretch perceived by the subject during the exercise execution. The experimental group students were asked to perform the stretching exercises when the stretched position was held gently until the end point of the range of motion was reached (i.e., stretch to the point of feeling tightness, but no pain). However, some of the studies did not report the intensity of the stretch used (Kamandulis et al., 2013; Rodríguez et al., 1999; Sainz de Baranda, 2009; Vidal, 1995). Future studies should control the intensity of the program assisted by objective instruments, as well as future studies should compare the effect of a light and moderate intensity.

Stretching exercises and stretching technique

Regarding the stretching exercises, in the most studies stretching exercises were performed correctly sensing and locating the stretch, properly positioning the spine, with curvatures of the dorsal and lumbar spine within normality (except for Kamandulis et al., 2013, and Vidal et al., 1995). The aligned column eliminates the increase in dorsal kyphosis that would be compensated for the limitation of the movement of the pelvis (Rodríguez & Santonja, 2001). However, bipodal exercises were also commonly used, which it needs a major control to maintain the column aligned (López Miñarro et al., 2011). Additionally, in all the studies, the postures were adopted gently and slowly until the final amplitude without feeling pain.

The sitting hip flexion and supine decubitus exercises with the knees extended were selected in some studies, due to the equilibrium conditions that guarantee during the execution and the stability of the knee in extension (Becerra-Fernández et al., 2016; Mayorga-Vega et al., 2015; Rodríguez et al. 1999, 2008; Sainz de Baranda, 2009; Useros & Campos, 2011). In addition to these postures some studies perform standing exercises (Mayorga-Vega et al., 2015; Nelson & Bandy, 2004; Reid & McNair, 2004; Useros & Campos, 2011). A pattern that increases the effectiveness of hamstring stretching exercises is the anteversion of the pelvis (Rodríguez & Santonja, 2001). Some of the programs take into account the placement of the pelvis in anteversion (Reid & McNair, 2004; Sainz de Baranda, 2009).

Regarding the stretching technique, most of the programs included static stretching techniques to improve flexibility. The static technique consists in a stretching maneuver where the target muscle is stretched slowly, while remaining relaxed and without muscle intervention in the involved joints, with certain intensity and subsequently that range of motion is held the established time. Since the static technique has showed to be effective to improve students' hamstring extensibility (in 10 of the 11 studies were used) and contributes to a greater control of the aligned arrangement of the spine, it seems that static technique is mainly recommended in high school students. Nevertheless, as several authors suggest (e.g., Behm et al., 2011; Turki-Belkhiria et al., 2014), dynamic stretching exercises may not be harmful when practiced in a soft and controlled way. In this line, three studies showed the effectiveness and safety of a dynamic stretching program (Becerra-Fernández et al., 2016; Van Rensburg & Coetzee, 2014; Vidal, 1995). Two studies were interested in determining whether there was a significant difference among the static and dynamic stretching techniques (Van Rensburg & Coetzee, 2014; Vidal, 1995). The results indicated there were not statistically significant differences between the static and dynamic techniques in order to improve students' hamstring extensibility. Therefore, future research might be interesting to apply similar programs using dynamic methods as active rebounds in high school students.

On the other hand, studies that compare different stretching techniques found similar results (Reid & McNair, 2004; Sainz de Baranda, 2009; Useros & Campos, 2011), except for the Useros and Campos's (2011) study where the students that used the Active Global Stretching (AGS) technique of obtained results slightly higher than the others. Stretching of muscle chains may be more effective at improving hamstring extensibility than analytical stretching.

Detraining and maintenance

Until now most studies only have focused on the benefits and gains existing in hamstring extensibility after application of stretching programs between two or more groups. However, only a few studies have examined how long they can retain these gains after a development program school-aged children (Becerra-Fernández et al., 2016; Mayorga-Vega et al., 2014c; Mayorga-Vega et al., 2014d; Merino-Marban et al., 2015). Particularly, only one study has been performed this feature in high school students (Becerra-Fernández et al., 2016).

Current scientific information about the flexibility detraining is really scarce and contradictory (Cipriani et al., 2012; Rancour, Holmes & Cipriani, 2009; Willy, Kyle, Moore, Chleboun, 2001), especially among school age children (Merino-Marban et al., 2015; Mayorga-Vega et al., 2014c; Mayorga-Vega et al., 2014d). Becerra-Fernández et al. (2016) observed that although a PE-based dynamic stretching intervention is effective to improve hamstring extensibility among high school school students, after four weeks of detraining students' flexibility reverts back to their baseline levels. Similarly, although Mayorga-Vega et al. (2014d) observed that primary schoolchildren retained significant gains, all the previous studies with primary schoolchildren found a statistically significant loss of hamstring extensibility after five weeks of detraining (Merino-Marban et al., 2015; Mayorga-Vega et al., 2014c).

Therefore, since after four to five weeks of flexibility detraining the effect of the stretching program are lost, PE teachers should continue training students' flexibility after a shorter detraining period in order to maintain the gains obtained in the previous semesters. Additionally, since the limited time allocation in PE (Hardman, Murphy, Routen, & Tones, 2014), teachers should teach to students how to correctly stretch and promote stretching habits. Since stretching programs cannot be allocated a large part of PE time, previous authors have suggested that PE teachers should include a maintenance program with reduced volume in order to retain students' flexibility levels gained during previous semesters (Viciano et al., 2014a; Viciano et al., 2014b). This way, apart from maintaining the flexibility levels previously obtained, such programs would allow teachers to address other PE curricular contents at the same time (Mayorga-Vega, Viciano & Cocca, 2013).

In this line, Becerra-Fernández et al. (2016) observed the effects of a dynamic stretching maintenance program on hamstring extensibility in female

high school students. The results of this study showed that a stretching maintenance program carried out only two minutes per session (i.e., the half volume) improves students' hamstring extensibility. Unfortunately, it must be highlighted that the values before the "maintenance" program were at the baseline levels and, therefore, strictly speaking it should be considered "resumption" or "re-development" instead of "maintenance". However, since the control students showed a significant decrease throughout the time, it seems that this program would allow avoid the apparently normal decline of flexibility at this age.

Test protocol

Regarding the test protocol, only five studies used angular tests to assess students' hamstring extensibility (Nelson & Bandy, 2004; Reid & McNair, 2004; Sainz de Baranda, 2009; Useros & Campos, 2011; Van Rensburg & Coetzee, 2014). Due to the necessity of several instruments (i.e., a stretcher, LumboSant or similar device, and a goniometer or inclinometer), two or more qualified evaluators, and time constraints, the use of these angular tests seem to be limited in several studies such as in the school setting (Becerra-Fernández et al., 2016; Kamandulis, Emeljanovas & Skurvydas 2013; Rodríguez et al., 1999; Rodríguez et al., 2008; Vidal, 1995). Since flexibility evaluation with goniometers and inclinometers are really sensitive methods, their use requires a certain technical qualification (Castro-Piñero et al., 2009). For example, for the Passive straight leg raise test, which is the most extended and recommend test for school-aged children (Mayorga-Vega et al., 2014), besides the variability in the determination of the raise leg end point based on the evaluated individual reported that the muscle tightness turn to pain and/ or the assistant evaluator palpable onset of posterior pelvic tilt, small changes in the grade of aligning of the goniometer axis with the hip joint, the aligning of the goniometer arms with the trunk and femur, the knee extension and ankle position of the evaluated leg, the contact of the contralateral leg, the external hip rotation, the pelvis rotation in the longitudinal axis and/ or the sagittal pelvis tilt may significantly affect the test score (López Miñarro et al., 2008; López-Miñarro et al., 2009; Mayorga-Vega et al., 2014). Additionally, angular hamstring extensibility tests require between two and three evaluators for each measure (Nelson & Bandy, 2004; Sainz de Baranda, 2009; López Miñarro et al., 2008; López-Miñarro et al., 2009). For example, while the main evaluator raises the leg and record the score, an assistant evaluator has to maintain the con-

tralateral leg extended and in contact with the stretcher, avoiding the external rotation, as well as the pelvis rotation in the longitudinal axis; and a second assistant evaluator have to fix and control the sagittal pelvis tilt (e.g., López Miñarro et al., 2008; López-Miñarro et al., 2009). Finally, since the individual has to lie down on the stretcher, the assistant evaluators has to fix the contralateral leg and pelvis, the main evaluator has to align the axis and the two arms of the goniometer, and at least two measures are require for each leg, they also are more time consuming compared with other protocols such as the lineal tests (Mayorga-Vega et al., 2014).

That is why the CSR is the most frequently used flexibility test in school setting because its procedure is simple, easy to administer, and only requires a one minimal trained evaluator (Castro-Piñero et al., 2009; López Miñarro et al., 2008). According to Mayorga-Vega, Merino-Marban and Viciano (2014a) the CSR test has a moderate mean criterion-related validity for estimating hamstring extensibility ($r_p = 0.67$), but not for estimating lumbar muscles extensibility that was very poor ($r_p = 0.26$). Consequently, when the use of angular tests is limited such as in a school setting or in large scale studies, scientists and practitioners could use the CSR test as a useful alternative for hamstring extensibility estimation (Mayorga-Vega et al., 2014). Only Useros and Campos (2011) examined the effect of a stretching program with both angular and lineal tests. However, since they only reported the change score, comparable effects sizes such as the d value could not be calculated. Regarding the between-study comparison, the median value showed that a significant lower effect magnitude (i.e., d value) was found among the intervention program that was evaluated with the lineal tests ($d = 0.45$) than with the angular test ($d = 1.99$). However, since several characteristics of the individual and programs could also vary between these studies, studies that compare the effect sizes reached with both kinds of tests are required. Additionally, as in the application of any physical fitness field test, it must be aware that the CSR test score is simply estimation and not a direct measure of hamstring extensibility (Mayorga-Vega et al., 2014). Therefore, future randomized

controlled studies that examine the effect of stretching programs by angular tests are required. Meanwhile those studies are performed, the findings with the lineal tests are also valuables. Firmer conclusions should await the accumulation of a larger number of cluster-randomized controlled trial studies sigle-blinded evaluated with angular tests in the PE setting.

A limitation of the studies was the fact that they did not take into account the alignment of the rachis during the stretching exercises and used the CSR is whether the improvements could be due to changes in the extensibility or changes in the disposition sagittal of the rachis (Kamandulis et al., 2013; Vidal, 1995). However, it is assumed that those studies that took into account the adequate alignment of the spine during the exercises would have avoided improvements due to changes in the sagittal arrangement of the spine (Becerra et al., 2016; Mayorga-Vega et al., 2015; Rodriguez et al., 1999, 2008).

Conclusions

A Physical Education-based stretching program produces a significant improvement of high-school students' hamstring extensibility levels. The results suggested that students should performed stretching programs at least for a duration of 5-6 weeks, a frequency of twice a week, and a volume per session of 30-60 s (20-30 s per set) to obtain improvements on hamstring extensibility. Stretching programs with higher duration, frequency and volume seems to obtain greater effects. However, after a four-week de-training period, students reverted back to their baseline levels. Although the most studies obtained flexibility improvements using static techniques, dynamic stretching exercises performed in a controlled manner also produced improvements and they were safety. Stretching programs should be included in Physical Education classes, specifically during the warm-up and the cool-down periods in order to improve hamstring extensibility. Teachers should implement stretching programs to improve the students' flexibility during the Physical Education classes.

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