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Research article

Effects of a Stretching Development and Maintenance Program on Hamstring Extensibility in Schoolchildren: A Cluster-Randomized Controlled Trial

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Abstract

The main purpose of the present study was to examine the effects of a physical education-based stretching development and maintenance program on hamstring extensibility in schoolchildren. A sample of 150 schoolchildren aged 7-10 years old from a primary school participated in the present study (140 participants were finally included). The six classes balanced by grade were cluster randomly assigned to the experimental group 1 (n = 51), experimental group 2 (n = 51) or control group (n = 49) (i.e., a *cluster randomized controlled trial* design was used). During the physical education classes, the students from the experimental groups 1 and 2 performed a four-minute stretching program twice a week for nine weeks (first semester). Then, after a five-week period of detraining coinciding with the Christmas holidays, the students from the experimental groups 1 and 2 completed another stretching program twice a week for eleven weeks (second semester). The students from the experimental group 1 continued performing the stretching program for four minutes while those from the experimental group 2 completed a flexibility maintenance program for only one minute. The results of the two-way analysis of variance showed that the physical education-based stretching development program significantly improved the students' hamstring extensibility ($p < 0.001$), as well as that these gains obtained remained after the stretching maintenance program ($p < 0.001$). Additionally, statistically significant differences between the two experimental groups were not found ($p > 0.05$). After a short-term stretching development program, a physical education-based stretching maintenance program of only one-minute sessions twice a week is effective in maintaining hamstring extensibility among schoolchildren. This knowledge could help and guide teachers to design programs that allow a feasible and effective development and maintenance of students' flexibility in the physical education setting.

Key words: Flexibility program, flexibility maintaining, classic sit-and-reach test, physical fitness, primary school children, physical education setting.

Introduction

Physical fitness is considered one of the most important health markers in childhood (Ortega et al., 2008), with flexibility being one of the key components of health-related physical fitness (Meredith and Welk, 2010). For instance, the lack of hamstring extensibility creates a decrease in pelvic mobility (López-Miñarro et al., 2012). Therefore, when individuals with poor hamstring extensibility perform a maximal trunk flexion with straight legs, a posterior pelvic tilt and an increase in spinal flexion occur (López-Miñarro et al., 2012). This invariably leads to biomechanical changes in the pressure distribution of the spine, which may condition spinal disorders (Carregaro and Coury, 2009). Particularly among children, low hamstring extensibility contributes to an increase in the risk of current low back pain (Feldman et al., 2001; Jones et al., 2005; Sjölie, 2004) and neck tension (Mikkelsson et al., 2006), as well as a higher risk of low back pain later in adulthood (Kujala et al., 1994).

Unfortunately, nowadays about one in five schoolchildren have a hamstring extensibility level indicative of health risk (Castro-Piñero et al., 2013). Therefore, health promotion policies should also be designed to identify schoolchildren with low hamstring extensibility as well as to encourage them to achieve healthy levels of extensibility. Regarding this public health issue, schools may play an important role in promoting health-enhancing flexibility levels (Ortega et al., 2008). Specifically, shortened hamstring muscles could be addressed proactively by systematically performing stretching exercises during physical education (PE) classes (Santonja Medina et al., 2007; Thacker et al., 2004). Current trends in most countries include requiring PE teachers to achieve and maintain schoolchildren's health-enhancing flexibility levels (e.g., Ministerio de Educación y Ciencia, 2006; National Association for Sport and Physical Education, 2005).

Previous studies have found that a PE-based stretching program carried out twice a week improves hamstring extensibility in schoolchildren (e.g., Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015; Sanchez Rivas et al., 2014). However, current PE teachers face several planning-related problems for developing students' flexibility levels (Viciana et al., 2014). For instance, many curricular contents must be developed each academic year. Therefore, stretching exercises cannot be allocated a large part of the time available in PE planning. Additionally, PE is usually limited by its restricted curriculum time allocation (Hardman, 2008), particularly when the weekly frequency of sessions is only twice a week, which is the norm in most European countries (European Commission/ EACEA/ Eurydice, 2013).

Another PE-based planning problem related to flexibility is its expected decrease after a period of detraining (Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015). On the one hand, besides the large volume of

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curricular contents in relation with the restricted curriculum time allocation, a limitation for PE-based planning is the fact that the academic year is frequently interrupted by several holiday periods such as Christmas holidays or Holy week (Viciana et al., 2014). On the other hand, many PE teachers conceive planning as “watertight drawers” that they have to fill with curricular contents (Siedentop and Tanehill, 2000). Therefore, PE teachers usually carry out stretching exercises in their classes only for some weeks, and when they cease doing them, they do not concern themselves with how long the effect will last (Merino-Marban et al., 2015). In this line, Viciana et al. (2014) suggested that after a stretching development program PE teachers should include a maintenance program in order to retain students’ flexibility levels throughout the whole academic year. Apart from maintaining the flexibility levels previously obtained, these programs would not interfere in the normal teaching of other PE curricular contents (Viciana et al., 2014).

Unfortunately, to our knowledge there are no previous studies examining the effect of a PE-based stretching maintenance program among schoolchildren. Consequently, the main purpose of the present study was to examine the effects of a PE-based stretching development and maintenance program on hamstring extensibility in schoolchildren. A secondary purpose of this study was to compare the effect of the PE-based stretching intervention program on hamstring extensibility according to the children’s flexibility baseline. It was hypothesized that a PE-based stretching development program would improve schoolchildren’s hamstring extensibility, as well as that a one-minute maintenance program would retain the flexibility gains obtained previously. Finally, it was also hypothesized that children with low hamstring extensibility would improve more than those with normal hamstring extensibility.

Methods

Participants

The study protocol was first approved by the Ethical Committee of the University of Granada. After the school approvals were obtained, schoolchildren and their legal guardians were fully informed about all the features of the study [i.e., a thorough description of the methods, potential risks, expected benefits, etc.; based on Thomas’s et al. (2015) guidelines] and were required to sign an informed consent document. A sample of 150 schoolchildren, 70 boys and 80 girls, aged 7-10 years old from six different third/ fourth-grade PE classes of a public primary school center participated in the present study. For practical reasons and the nature of the present study (i.e., intervention focused on natural groups in a school setting) a cluster randomized controlled trial design was used (Mayorga-Vega et al., 2013; Merino-Marban et al., 2015). The six natural classes balanced by grade were assigned randomly to form one of the following study groups: experimental group 1 (EG1), experimental group 2 (EG2) or the control group (CG).

All the participants were free of orthopedic disorders such as episodes of hamstring and/ or lumbar injuries, fractures, surgery or pain in the spine or hamstring and/ or lumbar muscles over the past six months. The inclusion criteria were: (a) correctly performing all the flexibility evaluations, and (b) having an attendance rate of 90% or higher for PE classes during the intervention period. Finally, although all the 150 invited schoolchildren agreed to participate, only 140 participants met the inclusion criteria. Figure 1 shows the flow chart that corresponds with the participants included in the present study. For general characteristics of the included participants, see the Results section.

Measures

Evaluation was carried out during the PE classes at the beginning and at the end of the stretching development program (pre-intervention and post-development, respectively) in order to examine possible changes produced. Subsequently, after a period of detraining (coinciding with the Christmas holidays) and the application of the stretching maintenance program, the participants were evaluated again in order to observe the levels of retention (post-maintenance). Each evaluation was carried out by the same evaluator, instrument, and under the same conditions. All the measures were taken in an indoor sports facility on the same day of the week and at the same time for each participant. Because of practical reasons, no warm-up exercises were performed prior to the test. The participants were assessed in sportswear and barefeet.

The classic sit-and-reach (SR) test was used to estimate participants’ hamstring extensibility. Briefly, at the beginning of the test the participants stood in front of the box, sat with their hips flexed, knees extended and both hands on the top of the ruler. From this position the participants had to bend the trunk forward slowly and progressively (no swings) in order to reach the furthest possible distance and to remain still for at least two seconds (a score of 16 cm corresponded to the tangent of the feet; accuracy ± 0.5 cm). The participants were allowed to perform the test twice with one minute apart and then the average score in cm was retained (Mayorga-Vega et al., 2015). Additionally, participants’ hamstring extensibility was categorized as follows: < 14.0 cm low and ≥ 14.0 normal hamstring extensibility (Ferrer, 1998). The SR test has demonstrated high reliability (ICC = 0.99) (Ayala et al., 2012) and adequate criterion-related validity (r_p = 0.67, 0.55-0.79) among children (Mayorga-Vega et al., 2014c).

Procedures

A stretching intervention program was applied to the EGs during the cool-down period of their PE sessions (Mayorga-Vega et al., 2014a). Initially, the EG students performed a four-minute stretching development program twice a week for nine weeks (first semester). Then, after a five-week period of detraining coinciding with the Christmas holidays, the EG participants completed another stretching intervention program twice a week for eleven weeks (second semester). The EG1 students continued performing the stretching intervention program for four minutes while the EG2 students completed a maintenance program for only one minute. Since two lessons of the

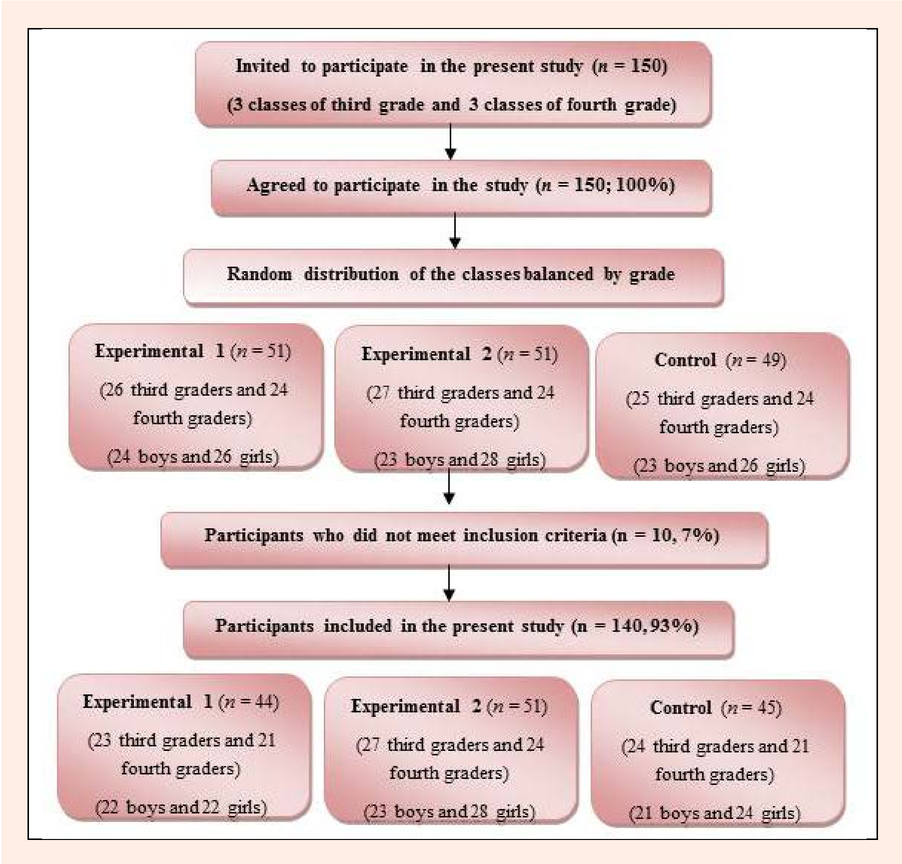

Figure 1. Flow chart corresponding to the participants included in the present study.

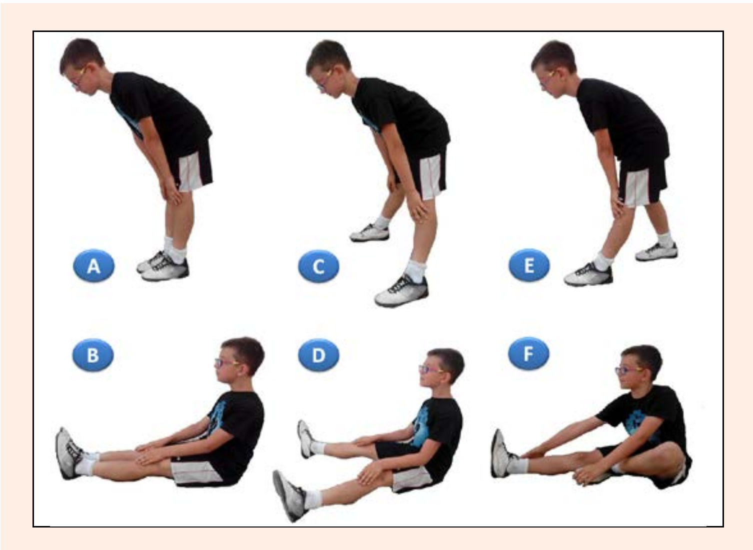

Figure 2. The six stretching exercises performed during the physical education-based stretching program were: (a) standing with feet together; (b) sitting with feet together; (c) standing with feet shoulder-width apart; (d) sitting with feet shoulder-width apart; (e) standing with only one leg extended, and (f) sitting with only one leg extended.

second semester coincided with holidays, in the end the EG participants completed a total of 18 and 20 sessions of the development and maintenance programs, respectively. In the PE setting the intervention performed with the EG2 has been called "reinforced teaching unit" (Viciana and Mayorga-Vega, 2015).

During each intervention session, the EG participants performed hamstring stretches using the static technique. Each intervention session included two 30-second sets of four stretching exercises (except for the maintenance sessions of the EG2 where only one stretching exercise was included). Six different stretching exercises were designed and alternated during the intervention program (Figure 2). Three bipodal exercises and one unipodal exercise were performed in each session (except for the maintenance sessions of the EG2 that only an exercise was performed). In all the stretching exercises, the students were placed with their hips flexed and knees extended. From this position the students flexed forward at the hip trying to maintain the spine in a neutral position as much as possible until a gentle stretch was felt in the hamstrings. 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 the tightness, but no pain). Once this position was achieved, the participants held it for 30 seconds. During the first two sessions of the intervention the PE teacher explained in depth how to properly perform the stretching exercises. Additionally, students also received constant feedback on their execution every session during the whole intervention. On the other hand, since teaching how to properly develop flexibility is a mandatory objective for PE in Spain (Ministerio de Educación y Ciencia, 2006), schoolchildren learn how to perform stretching exercises from the first grade of schooling (i.e., 6 years old).

All the students were urged to maintain their normal levels of physical activity outside the supervised setting during the research period. During the intervention program period all the students participated in their standard PE sessions. However, the CG students did not perform stretching exercises and were not aware of the purpose of the study. Both the standard PE sessions and the stretching intervention programs were carried out by the same PE teacher of the participating center for all the groups.

Statistical analysis

Descriptive statistics (means ± standard deviations or frequency) for age, gender, body mass, body height, body mass index, extracurricular sport, hamstring extensibility, and SR scores were calculated. A one-way analysis of variance (ANOVA) was conducted to examine potential differences between the three groups in terms of body mass, body height, body mass index, and baselines values of the SR test. Additionally, a chi-squared analysis was carried out to test the ratio differences of gender, extracurricular sport and pre-intervention hamstring extensibility categories between the three groups. The reliability of the SR scores was estimated using the intraclass correlation coefficient from the two-way ANOVA (Shrout and Fleiss, 1979), as well as the 95% confidence interval.

Afterwards, the effect of the PE-based development and maintenance program on hamstring extensibility was examined using a two-way ANOVA applied over the SR scores, including *group* as an independent variable (EG1, EG2, CG) and *time* as a dependent variable (pre-intervention, post-development, post-maintenance). Subsequently, the *post hoc* analyses with the Bonferroni adjustment was used for both between or within-groups pairwise comparisons. Moreover, the Hedges' *g* effect size was used to examine the magnitude of the intervention effects (Hedges, 2007). The minimal detectable change was calculated in order to examine if the change score due to the intervention was true and reliable rather than the measurement error (Haley and Fragala-Pinkham, 2006).

On the other hand, the exacted McNemar's test was calculated in order to examine if the PE-based stretching development and maintenance program increased the proportion of children with normal hamstring extensibility. Finally, the two-way ANOVA, Hedges' *g* effect size, and minimal detectable change were also calculated in order to examine the effect of the PE-based stretching intervention program on hamstring extensibility according to the children's flexibility baseline. For this last purpose, since most of the schoolchildren with low hamstring extensibility moved to a normal hamstring extensibility level after the development program and the total experimental sample was divided into two different interventions during the maintenance program period, data from both EGs were combined and only the effect of the development program was examined. All statistical analyses were performed using the SPSS version 20.0 for Windows (IBM® SPSS® Statistics 20). The statistical significance level was set at $p < 0.05$.

Results

Table 1 shows the general characteristics of the participants studied. The one-way ANOVA results did not show statistically significant differences in body mass, body height, body mass index, and SR baseline values between groups ($p > 0.05$). Furthermore, the chi-square analysis showed that the three groups had a balanced representation of boys/ girls, extracurricular sport practitioners/ non-practitioners, and low/ normal hamstring extensibility ($p > 0.05$). The reliability of the SR scores was 0.97 (0.96-0.98).

Table 2 shows the effect of the PE-based stretching intervention program on hamstring extensibility levels. The results of the two-way ANOVA on the average obtained in the SR test showed a statistically significant

Table 1. General characteristics of the participants and differences between the experimental and control groups. Data are reported as means (±standard deviation) or frequency.

	Experimental 1 (*n* = 44)	Experimental 2 (*n* = 51)	Control (*n* = 45)	p[a]
Age (years)	8.5 (.8)	8.4 (.8)	8.4 (.6)	-
Gender (boys/ girls)	22/ 22	23/ 28	21/ 24	.890
Body mass (kg)	33.8 (7.5)	33.7 (7.7)	36.6 (11.5)	.229
Body height (m)	1.33 (.06)	1.32 (.06)	1.33 (.08)	.843
Body mass index ($kg·m^{-2}$)	19.0 (3.4)	19.1 (3.4)	20.4 (4.4)	.124
Extracurricular sport (yes/ no)[b]	33/ 11	28/ 23	25/ 20	.082
Pre-intervention score (cm)	16.8 (5.4)	16.8 (5.5)	15.3 (5.2)	.320
Hamstring extensibility (low/ normal)	15/ 29	15/ 36	18/ 27	.551

[a] Significance level from the chi squared test for the ratio of gender, extracurricular sport, and pre-intervention hamstring extensibility categories, and from the one-way analysis of variance for body mass, body height, body mass index, and pre-intervention scores of the sit-and-reach test; [b] Children that regularly participated (yes) or not (no) at least twice per week in extracurricular sport activities.

Table 2. **Effect of the physical education-based stretching program on hamstring extensibility (classic sit-and-reach scores, cm). Data are reported as means (±standard deviation).**

Group	Pre-intervention (1)	Post-development (2)	Post-maintenance (3)	p^a	Effect size[b] 1-2	2-3	1-3
EG1 (n = 44) ##	16.8 (5.4)	19.5 (6.0) ***	20.1 (5.6) ***	<.001	.49	.03	.52
EG2 (n = 51) #	16.8 (5.5)	19.1 (5.1) ***	19.1 (5.0) ***		.42	- .10	.33
CG (n = 45)	15.3 (5.2)	15.4 (4.9)	15.8 (5.7)		.07	.13	.20

EG1, experimental group 1; EG2, experimental group 2; CG, control group; [a] Significance level from the two-way analysis of variance with the *post hoc* analyses with Bonferroni adjustment. Between-groups pairwise comparisons: Differences statistically significant from CG (# p < 0.05, ## p < 0.01). Within-groups pairwise comparisons: Change statistically significant from pre-intervention to post-development and from post-development to post-maintenance (*** p < 0.001); [b] Hedges' *g* effect size. Rows from top to bottom: EG1-CG, EG2-CG, and EG1-EG2.

Table 3. **Effect of the physical education-based stretching intervention program on the proportion of children with normal hamstring extensibility. Data are reported as frequency (% total).**

		Experimental group 1			Experimental group 2			Control group		
		Post-development			Post-development			Post-development		
		Low	Normal	Total	Low	Normal	Total	Low	Normal	Total
Pre-intervention	**Low**	7 (15.9)	8 (18.2)	15 (34.1)	4 (7.8)	11 (21.6)	15 (29.4)	14 (31.1)	4 (8.9)	18 (40.0)
	Normal	1 (2.3)	28 (63.6)	29 (65.9)	2 (3.9)	34 (66.7)	36 (70.6)	6 (13.3)	21 (46.7)	27 (60.0)
	Total	8 (18.2)	36 (81.8)	44 (100.0)	6 (11.8)	45 (88.2)	51 (100.0)	20 (44.4)	25 (55.6)	45 (100.0)
	p^a			.039			.022			.754
		Post-maintenance			Post-maintenance			Post-maintenance		
		Low	Normal	Total	Low	Normal	Total	Low	Normal	Total
Post - development	**Low**	4 (9.1)	4 (9.1)	8 (18.2)	2 (3.9)	4 (7.8)	6 (11.8)	17 (37.8)	3 (6.7)	20 (44.4)
	Normal	2 (4.5)	34 (77.3)	36 (81.8)	7 (13.7)	38 (74.5)	45 (88.2)	2 (4.4)	23 (51.1)	25 (55.6)
	Total	6 (13.6)	38 (86.4)	44 (100.0)	9 (17.6)	42 (82.4)	51 (100.0)	19 (42.2)	26 (57.8)	45 (100.0)
	p^a			.687			.549			1.000

[a] Significance level from the McNemar's test.

interaction effect between the group and time variables [F(4, 274) = 6.177; p < 0.001; η2 = 0.083; p = 0.987]. Subsequently, the between-group pairwise comparisons with the Bonferroni adjustment showed that both the EG1 and EG2 were statistically significantly different than the CG (p < 0.05). Nevertheless, statistically significant differences between the EG1 and EG2 were not found (p > 0.05). Regarding the within-group analyses, the pairwise comparisons with the Bonferroni adjustment showed that both the EG1 and EG2 statistically significantly improved hamstring extensibility from pre-intervention to post-development (p < 0.001) and from pre-intervention to post-maintenance (p < 0.001). However, for both the EG1 and EG2 from post-development to post-maintenance no statistically significant differences were found (p > 0.05). Additionally, statistically significant differences were not found for the CG (p > 0.05). The minimal detectable change value of the SR score was 2.2 cm, when the average increase in the EG1 was 2.7 and 3.3 cm and in the EG2 2.4 and 2.3 cm for the pre-intervention-post-development and pre-intervention-post-maintenance, respectively.

Table 3 shows the effect of the PE-based stretching intervention program on the proportion of children with normal hamstring extensibility. The results of the exact McNemar's test showed that for both the EG1 and EG2 there was a statistically significant increase on the proportion of children with normal hamstring extensibility from pre-intervention to post-development (p < 0.05). Additionally, for both the EG1 and EG2 from post-development to post-maintenance no statistically significant differences were found (p > 0.05). On the other hand, statistically significant differences were not found for the CG (p > 0.05).

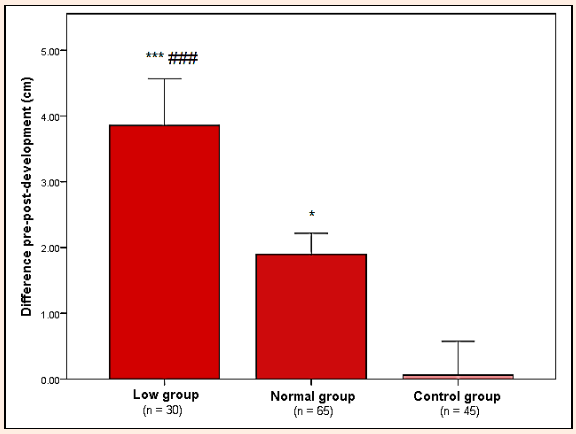

Figure 3. **Effect of the physical education-based stretching intervention program on hamstring extensibility according to the children's flexibility baseline (classic sit-and-reach scores, cm). The values represent the mean and the error bars the standard error.** Between-groups pairwise comparisons: Statistically significant differences between the low/ normal groups and the control group (* p < 0.05; *** p < 0.001) and between the low group and normal group (### p < 0.001).

Figure 3 shows the effect of the PE-based stretching intervention program on hamstring extensibility according to the children´s flexibility baseline. The results of the two-way ANOVA on the average obtained in the SR test showed a statistically significant interaction effect between the group and time variables [F(2, 137) = 12.998; p < 0.001; η^2 = 0.159; p = 0.997]. Subsequently, the between-group pairwise comparisons with the Bonferroni adjustment showed that both the low and normal groups were different than the CG in a statistically significant manner (p < 0.05; g = 0.70 and 0.34, respectively). Additionally, statistically significant differences between the low and normal groups were found in favor of students with low flexibility baseline levels ($p < 0.001$; $g = 0.36$). Regarding the within-group analyses, the pairwise comparisons with the Bonferroni adjustment showed that both the low and normal groups had a statistically significant improvement in hamstring extensibility from pre-intervention to post-development ($p < 0.001$). However, statistically significant differences were not found for the CG ($p > 0.05$). Although the average increase in the children with low hamstring extensibility (3.9 cm) was above the minimal detectable change value (i.e., 2.2 cm), in the students with normal hamstring extensibility it was slightly below (1.9 cm). On the other hand, while in the low group there was an important amount of children that after development intervention program moved to normal hamstring extensibility (63.3%; low 11/ normal 19), in the normal group the amount of children with normal hamstring extensibility was retained (95.4%; low 3/ normal 62). As regards the CG, there were not found important changes in the proportion of children with normal hamstring extensibility from the pre-intervention (60.0%; low 18/ normal 27) to post-development (55.6%; low 20/ normal 25).

Discussion

The main purpose of this study was to examine the effects of a PE-based stretching development and maintenance program on hamstring extensibility in schoolchildren. Similarly to previous studies carried out only twice a week (e.g., Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015; Sanchez Rivas et al., 2014), the findings of the present study have shown that a PE-based stretching development program improves hamstring extensibility in schoolchildren. Furthermore, these outcomes also showed that the short-term stretching development program increased the proportion of schoolchildren with normal hamstring extensibility. Regarding the magnitude effects of the development program, in the present study the effect size of the stretching development program was moderate, indicating that the intervention was effective. Similarly to the present results, all the previous studies carrying out short-term PE-based stretching programs obtained on average similar effect sizes (g = 0.43) (Kamandulis et al., 2013; Mayorga-Vega et al., 2014a; 2014b; Merino-Marban et al., 2015; Sánchez Rivas et al., 2014).

Increasing training factors such as the frequency or duration of the stretching intervention program could have a positive consequence on the magnitude effects. In regard to the frequency of the stretching program, Santonja et al. (2007) found that when the children performed four sessions per week instead of two, the magnitude effect doubled (twice a week, g = 0.85; four times a week, g = 1.53; both 5 minutes per session, 31 weeks of duration). However, since in most European countries PE is limited to only two sessions per week (European Commission/ EACEA/ Eurydice, 2013), the application of stretching programs with a high frequency is not feasible in this educational setting. Merino-Marban et al. (2015) indicated that the increase of active time for learning in extra-curricular periods would represent an excellent strategy for PE teachers to pursue important objectives such as the flexibility improvement. Nevertheless, since this strategy mainly depends on the students' autonomy, we have to be aware that in primary schoolchildren it could be impractical (Merino-Marban et al., 2015).

In regard to the duration of the stretching program, while the previous studies examining the short-term stretching programs effects (5-10 weeks) obtained similar effect sizes as the current study (g = 0.43, 0.24-0.67) (Kamandulis et al., 2013; Mayorga-Vega et al., 2014a; 2014b; Merino-Marban et al., 2015; Sánchez Rivas et al., 2014), the magnitude was higher for the mid-term stretching programs (16 weeks) (g = 0.86, 0.85-0.88) (Coledam et al., 2012), and even higher for those with long-term stretching programs (whole school year, 31-32 weeks) (g = 0.94, 0.85-2.06) (Rodríguez et al., 2008; Sainz de Baranda 2009; Sainz de Baranda et al., 2006; Santonja Medina et al., 2007). However, in most European countries the application of a stretching development program with a relatively high time per session during the whole academic year is not suitable in the PE setting (Viciana et al., 2014).

Since stretching programs cannot be allocated a large part of PE time, Viciana et al. (2014) suggested that PE teachers should include a maintenance program with a reduced volume in order to retain students' flexibility levels gained during the previous semesters. The results of the present study showed that a PE-based stretching maintenance program carried out only one minute per session (i.e., the 25% volume of stretching per session than in the previous development program) retains schoolchildren's hamstring extensibility gains previously obtained. Additionally, the results of this study showed that the one-minute maintenance program was not different comparing to the four-minute maintenance program (i.e., when the EG students continued performing the same volume of stretching that in the previous development program). Similarly, the findings of this study also showed that the one-minute maintenance program retained the number of schoolchildren with normal hamstring extensibility as the four-minute maintenance program did. However, as regards the effect size, although the maintenance program carried out for one minute per session was also moderate, the magnitude of the EG participants that were enrolled in sessions for four minutes was slightly higher.

Regarding the previous literature, studies examining the effect of a stretching maintenance program in schoolchildren were not found, and the number of related studies with adults was scarce as well. On the one hand, Rancour et al. (2009) found that, after a daily development stretching program, with 2-3 sessions per week the adults also maintained the flexibility levels previously gained. On the other hand, Willy et al. (2001) carried out a study with adults that stretched five days per week for six weeks followed by four weeks of cessation and then they carried out six weeks of resumption following the same protocol as in the development program. Similar to the results of the current study with the EG1 (although after the resumption program adults obtained statistically significantly gains) the scores obtained were similar that at the end of the development program.

A secondary purpose of the present study was to compare the effect of the PE-based stretching intervention program on hamstring extensibility according to the children's flexibility baseline. The results of this study showed that both schoolchildren with low and normal flexibility baseline levels improved their hamstring extensibility. However, this improvement was higher among the children with low hamstring extensibility than those with normal flexibility baseline levels. Unfortunately, to our knowledge there are no previous studies examining the influence of the children's flexibility baseline levels on the effect of a PE-based stretching intervention program. Similarly to the present study, Mayorga-Vega and Viciana (2015) examined the effects of a PE-based physical fitness program on cardiorespiratory fitness according to the students' baseline levels. Although previous authors also found that the students with a lower physical fitness baseline improved their cardiorespiratory fitness levels, no significant differences between the students with higher levels and control students were found. In this line, despite the fact that in the present study significant differences were found for both experimental groups against the CG, only the increase in the children with low hamstring extensibility was above the minimal detectable change value. This points out that the improvement score observed in the students with normal hamstring extensibility could be not true and reliable rather than the measurement error (Haley and Fragala-Pinkham, 2006). Moreover, meanwhile the effect size of the stretching development program for schoolchildren with low hamstring extensibility was high, for their classmates with normal baseline flexibility levels the improvement was low.

Finally, as regards the physiological mechanics responsible for the increase in hamstring extensibility found, some theories have been proposed. Traditionally, most of the theories suggest that the increases in muscle extensibility observed after a stretching program involve a mechanical increase in length of the stretched muscle. These theories, which are known as "Mechanical theories", include viscoelastic deformation, plastic deformation, increased sarcomeres in series, and neuromuscular relaxation. Nevertheless, up to date evidence does not support any of these theories. Firstly, although some experimental studies found that muscle length does increase during stretch application due to the viscoelastic deformation of muscle, all of these studies consistently showed viscoelastic deformation to be transient. Then, there is simply no empirical evidence of a plastic deformation phase in muscles. Regarding the increased sarcomeres in series, studies with animals have demonstrated that when muscles are immobilized in a fully extended position, there is an increase in the number of sarcomeres in series. However, these muscles do not undergo overall change in muscle length because it is offset by a concurrent decrease in sarcomere length. Finally, it has also often been suggested that involuntary contraction of muscles due to a neuromuscular "stretch reflex" can limit muscle elongation during stretching and, therefore, individuals should stretch slowly in order to stimulate neuromuscular reflexes that induce relaxation of muscles. Nevertheless, no study has supported the above mentioned assertions.

More recently, a new theory, which is referred as the "Sensory theory", suggests that increases in muscle extensibility are only due to a modification of individual's sensation and not to an increase in muscle length. Most of the studies support the notion that increases in muscle extensibility observed after a single stretching session and after short-term stretching programs are due to a modification of the individual's sensation. However, the effects of mid-term and long-term stretching programs have not yet been examined. Therefore, in the present study the increases in hamstring extensibility observed after the short-term stretching development program could be explained only by modifications in children's sensation. Likewise, the Sensory theory may also explain the retention in hamstring extensibility during the stretching maintenance program. A more extensive explanation of physiological mechanisms of improvements in muscle extensibility due to a stretching program can be found elsewhere (e.g., Gajdosik, 2001; Weppler and Magnusson, 2010).

Limitations and future research studies

One of the most important limitations of the present study was to not perform a warm-up during the flexibility evaluation sessions. Although it has been observed that performing a warm-up increases the flexibility test scores (Díaz-Soler et al., 2015; O'Sullivan et al., 2009; Ryan et al., 2014), in the present study no warm-up exercises were performed. Firstly, previous studies have shown that the acute effect of a warm-up only lasts some minutes (DePino et al., 2000; O'Sullivan et al., 2009; Spernoga et al. 2001). Secondly, the effects differ significantly if the test is performed immediately after the warm-up or after a certain time (DePino et al., 2000; Díaz-Soler et al., 2015; O'Sullivan et al., 2009; Spernoga et al. 2001). However, because of practical reasons, the test would be only executed after a warm-up by all students simultaneously, but because of the order of assessment, some students would take the test immediately after finishing the warm-up and others would do it after several minutes. Therefore, in order to ensure the same conditions for all the participants (i.e., avoiding extraneous variables), no warm-up exercises were performed prior to the SR test.

On the other hand, since in the present study the pre-intervention values were assessed, any change in the participants' flexibility was compared with their baseline levels. Therefore, it could reasonably assume that any change in participants' hamstring extensibility due to the stretching intervention compared to their pre-intervention values would be the same after the application or not of a warm-up protocol (i.e., following the same protocol in each flexibility evaluation session). In this line, similarly to the present study, none of the previous studies examining the effect of stretching intervention programs in schoolchildren performed warm-up exercises prior to the flexibility evaluation (e.g., Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015; Rodríguez et al., 2008; Sainz de Baranda 2009; Santonja Medina et al., 2007). Furthermore, since in the numerous previous studies no injury was reported as in the present study, not performing a warm-up prior to the flexibility evaluation is demonstrated to be completely safe among children.

Another important limitation in the present study was the fact that the post-detraining values were not measured. Although hamstring extensibility improvements are expected to decrease after a period of detraining (Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015), the PE-based stretching programs are frequently interrupted by several holiday periods (Viciana et al., 2014). Regrettably, in the current study the detraining effect during the Christmas holidays could not be examined for practical reasons. However, previous studies where a PE-based stretching program was carried out observed statistically significant loss of hamstring extensibility after five weeks of detraining (Mayorga-Vega et al., 2014b; Merino-Marban et al., 2015). Therefore, PE teachers should employ some didactic strategies that encourage students to perform stretching exercises outside the PE setting (Viciana et al., 2014). Future research interventions should examine the effectiveness of these kinds of interventions for maintaining the flexibility levels during the long holidays such as Christmas or summer. Additionally, future research studies should also examine in depth the effects of different maintenance stretching programs in order to retain the flexibility gains obtained previously.

Conclusion

The results of the present study first suggest that a short-term, four-minute development program improves students' hamstring extensibility, also increasing the proportion of schoolchildren with normal hamstring extensibility. Secondly, another important finding is the fact that it is possible to maintain students' hamstring extensibility only with one-minute sessions twice a week in a PE setting. Since only 2% of the PE time in a common situation of 50-minute sessions twice a week was used, apart from maintaining the flexibility levels previously obtained, these programs would not interfere in the normal teaching of other curricular PE contents. Finally, the results of this study show that schoolchildren with low hamstring extensibility improved greater than those with normal hamstring extensibility. This knowledge could help and guide teachers to design programs that allow a feasible and effective development and maintenance of students' flexibility in the PE setting.

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Key points

- A physical education-based stretching maintenance program of only one-minute sessions twice a week is effective in maintaining hamstring extensibility among schoolchildren.
- A four-minute maintenance program shows similar effects that the one-minute maintenance program on hamstring extensibility among schoolchildren.
- Physical education teachers and other practitioners could carry out one-minute programs for a feasible and effective maintenance of students' flexibility.

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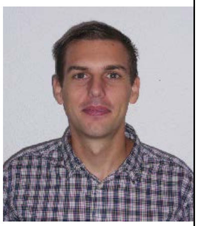

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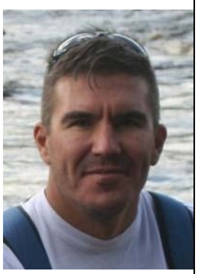

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