Improving hamstring flexibility through physical education based interventions: a systematic review and meta-analysis

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doi: 10.18176/archmeddeporte.00074

Recibido: 15/03/2021
Aceptado: 28/10/2021

Summary

Flexibility is recognized as a strong marker of physical health in children. Scientific research has indicated that there is a worldwide decline in children's physical fitness, including a reduction in flexibility levels. It has been suggested that a lack of flexibility in youth may be responsible for several health complications, including back pain, injury risk, and posture problems. Physical education (PE) classes are part of the school curriculum, which are an ideal setting to improve children physical fitness levels. The purpose of this systematic review and meta-analysis was to investigate whether incorporating a stretching component during regular PE classes can improve flexibility in school children. Three electronic databases were searched systematically until June 2019 for studies analysing the effects of interventions performed during PE classes aimed to improve the flexibility levels of school children (6-18 years). The critical appraisal was carried using PEDro and MINORS scales and a meta-analysis was performed. Seventeen studies of moderate-to-high methodological quality were included in the review and 14 in the meta-analysis, pooling 874 participants. The interventions showed significant improvements in the flexibility of the children, although the relative influence of genre could not be further analysed, due to the fact that insufficient data was reported. The meta-analysis for the hamstring flexibility resulted in a significant moderate effect. Flexibility levels can be improved through the incorporation of stretching interventions during PE classes, since flexibility is a key health-related physical fitness componentFurther research is needed on the effects of such interventions on trunk and upper body flexibility.

Key words:
Children. Health. Physical education. Flexibility.

Mejora de la flexibilidad de isquiotibiales a través de intervenciones basadas en educación física: una revisión sistemática y un meta-análisis

Resumen

La flexibilidad es un fuerte indicador de la salud física de los niños. La investigación científica ha indicado que hay una disminución mundial en la condición física de los niños, incluida una reducción en los niveles de flexibilidad. Las clases de educación física (EF) que forman parte del curriculum, son un entorno ideal para mejorar los niveles de aptitud física de los niños. El propósito de esta revisión sistemática y metanálisis fue investigar si la incorporación de estiramientos durante las clases regulares de educación física puede mejorar la flexibilidad en los niños en edad escolar. Se realizaron búsquedas sistemáticas en tres bases de datos electrónicas hasta junio de 2019 en busca de estudios que analizaran los efectos de las intervenciones realizadas durante las clases de EF destinadas a mejorar los niveles de flexibilidad de los escolares (6-18 años). La valoración crítica se realizó mediante escalas PEDro y MINORS y se realizó un metaanálisis. En la revisión se incluyeron 17 estudios de calidad metodológica de moderada a alta y 14 en el metanálisis, que agruparon a 874 participantes. Las intervenciones mostraron mejoras significativas en la flexibilidad de los niños, si bien la influencia del género no se pudo analizar en profundidad, debido a la existencia de insuficiente información al respecto. El metanálisis de la flexibilidad de los isquiotibiales resultó en un efecto moderado significativo. Los niveles de flexibilidad se pueden mejorar mediante la incorporación de intervenciones de estiramiento durante las clases de educación física. Se necesitan más investigaciones sobre los efectos de tales intervenciones en la flexibilidad del tronco y la parte superior del cuerpo.

Palabras clave:
Niños. Salud. Educación física. Flexibilidad.

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Introduction

Flexibility is recognized as a strong marker of physical health in children, representing one of the main components of health-related physical fitness[1]. Indeed, it has been suggested that a lack of flexibility in youth may be responsible for several health complications, including back pain, injury risk, and posture problems[2]. For instance, reduced hamstring flexibility has been shown to negatively affect pediatric posture in children[3], while reduced trunk flexibility has been identified as a risk factor for developing lumbar vertebrae stress[4]. A lack of flexibility in younger people has also been associated with a higher risk of developing low back pain[5]. Finally, it has been reported that children with limited joint flexibility exhibit lower levels of motor competence[6], which is considered a key factor for developing a healthy lifestyle[7].

Scientific research has indicated that there seems to be a worldwide decline in children's physical fitness[8], including a reduction in flexibility levels. Indeed, secular trends have demonstrated that youth in the present day are less flexible than those in the 1980s[9] 90s and 00s[10]. These findings highlight the importance of developing and promoting adequate flexibility among children. However, current guidelines developed by the government and institutions for promoting fitness development in this population are mainly focused on aerobic and muscular fitness, resulting in flexibility often being overlooked[11]. Therefore, alternative strategies must be found to increase the motivation for children to improve their flexibility levels.

Physical education (PE) classes are part of the school curriculum, which are an ideal setting to improve children physical fitness levels. Indeed, PE is the most effective time to promote physical activity during the school day, and most countries have legal requirements to incorporate PE during at least part of the compulsory schooling years[12]. As a result, PE classes may be a useful opportunity to implement interventions aimed to improve the flexibility of children. To the best of the authors' knowledge, however, no study has critically reviewed the existing scientific evidence and assessed the potential benefits of these interventions. Thus, the purpose of this systematic review and meta-analysis was to investigate whether incorporating a stretching component during regular PE classes can improve flexibility in school children.

Material and method

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The selected search strategy and methods of analysis were registered in the PROSPERO database.

Search strategy

Three electronic databases (MEDLINE/PubMed, SPORTDiscuss and Scopus) were searched systematically from their inception until June 2019. The following search terms, Boolean operators, and combinations were used: "Flexibility" OR "Stretching" AND "Physical Education" OR "School".

Eligibility criteria

Studies that provided information regarding the effects of interventions performed during PE classes aimed to improve the flexibility levels of school children (6-18 years) were considered eligible. Investigations were excluded if: a) the intervention included other activities performed outside PE classes; b) the intervention was based on the performance of a single exercise training session; and c) the research was not written in English, Portuguese or Spanish.

Study selection

Two authors screened the titles and abstracts of the identified studies for eligibility. After independently reviewing the selected studies for inclusion, these were compared by both authors to reach an agreement. Once the agreement had been reached, a full-text copy of every potentially relevant study was obtained. If it was unclear whether the study met the selection criteria, advice was sought from a third author and a consensus was reached.

Data extraction

Information on participants' characteristics, training program details, drop-outs and outcomes were extracted from the original reports by one researcher and checked by a second investigator. Missing data were obtained from the study authors, whenever possible.

Quality appraisal

The methodological quality of the selected RCTs was directly retrieved from the Physiotherapy Evidence Database (PEDro). The quality appraisal of those RCTs not rated in PEDro was performed by two authors independently with discrepancies in ratings arbitrated by a third author. In case of disagreement, advice was sought for a third author. The suggested cut-points to categorize studies by quality were excellent[9–10], good[6–8], fair[4–5] and poor (≤ 3)[13].

The methodological index for non-randomized studies (MINORS)[14] was used to perform the quality appraisal of those investigations in which the participants were not randomly assigned to intervention and control groups. These studies were evaluated as comparative investigations by two independent authors. For these cases, the MINORS includes 12 items with a maximum score of 24 points. Quality for these scores were interpreted as high[19–24], moderate[13–18], low[7–12], and very low (≤ 6)[14].

Data analysis

A meta-analysis was performed on all the studies in which the results obtained by the experimental and the control groups were compared, provided that the same outcomes had been assessed in at least two studies in a comparable way[15]. In addition, a sensibility analysis was performed analyzing the results separately for the RCTs and non-RCTs. Pre- and post-intervention data were presented for the intervention and control groups as mean ± standard deviation (SD). Standardized mean differences (SMD) and their 95% confidence intervals (CIs) were calculated to assess the change for each outcome variable. For studies with multiple comparison groups, the Cochrane Handbook of Systematic Reviews of Interventions recommendations and its formula to combine groups were used to merge the data into a single effect size, in order to avoid double-counting.

To obtain the pooled effects, both a fixed effect and a random effects model were applied. In cases with a heterogeneity level (I-squared) over 30%, the random effects model was used. Forest plots displaying SMD and 95% CIs were used to compare the effects between the pre- and post-intervention measurements in the intervention and control groups. SMDs were significant when their 95% CIs excluded zero, while pooled SMD values of less than ± 0.2, ranging from ± 0.2 to ± 0.8, or greater than ± 0.8 indicated the existence of small, medium, or large effects, respectively. Meta-regression was used for moderator analysis because it reduces the probability of Type I error by computing concurrent estimates of independent effects by multiple moderators on the variation in effect size across trials. All statistical analyses were performed using Stata 13.

Results

A total of 49,659 references were initially obtained. Duplicates were removed, and then the titles and abstracts of 62 investigations were screened for eligibility. After assessing the full texts for inclusion and exclusion criteria, a total of 17 investigations[16-33] were finally included in qualitative analysis and 12 were included in the meta-analysis (Figure 1).

Study characteristics

All studies included children or adolescents, with ages ranging between 5 and 17 years old. The full characteristics of each study can be found in (Table 1).

In general, participants were free from preexisting conditions such as orthopedic, musculoskeletal, and/or spinal pathologies (n = 14). Only three studies excluded participants if they were already engaging in another form of structured physical activity[16,17] or sport[18]. The length of

Figure 1. Flow diagram.

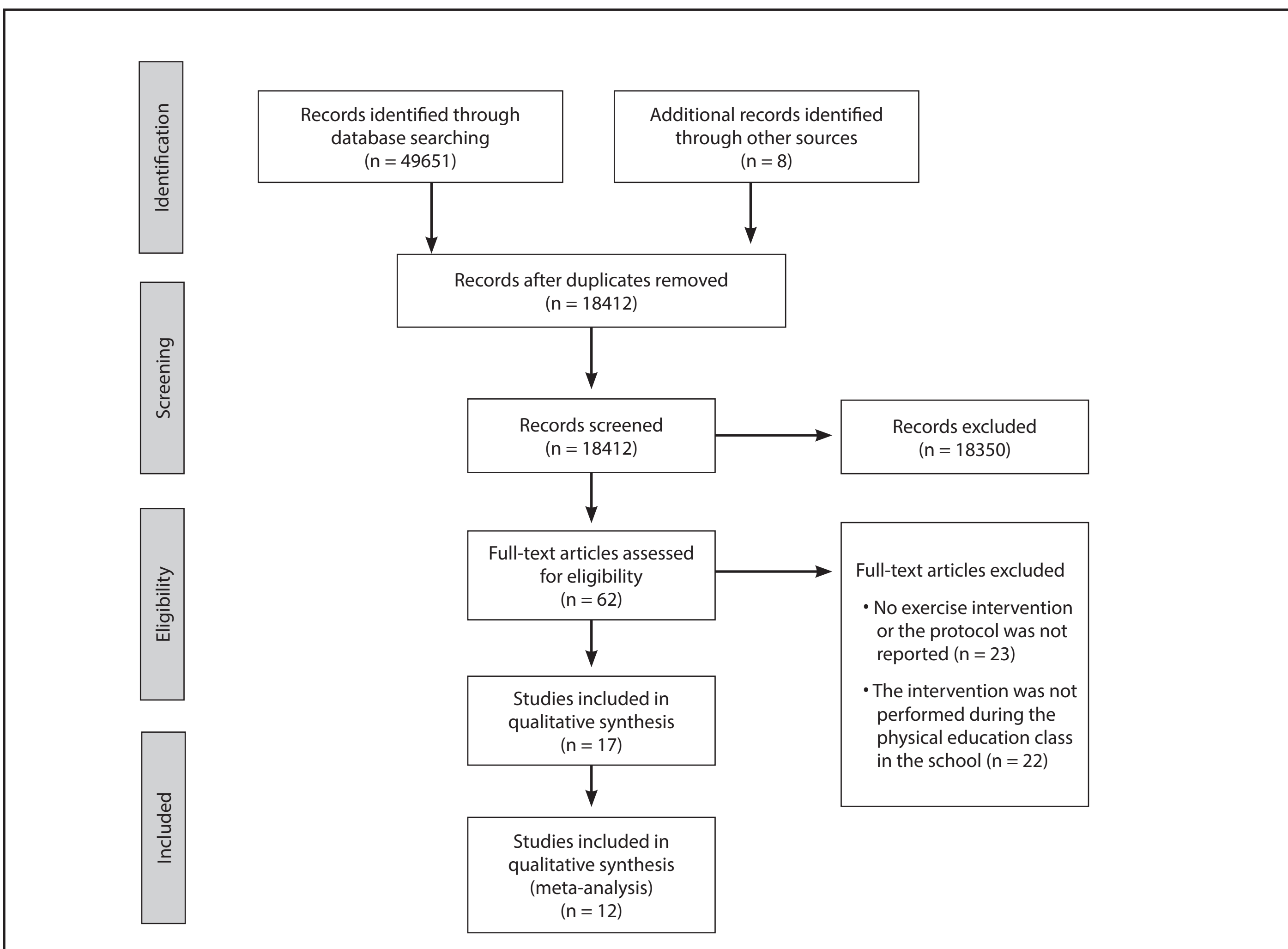

Table 1. Characteristics of the Studies Included in the Systematic Review.

Author (Year)	Participants	Intervention and Control Groups	Responsive Outcomes	Flexibility Scores	Flexibility Differences
Useros-García, 2010[18]	IG1: *n* = 12 (16-17 years) IG2: *n* = 12 (16-17 years) CG: *n* = 9 (16-17 years) Inclusion Criteria: N/R Exclusion Criteria: Practice regular sports; pathology or pain.	Length: 5 weeks IG1: 30 minutes, twice per week of active global stretching. Stretches were held for 4-10 minutes, depending on the characteristics of the postures. IG2: 30 minutes of moderate-intensity analytical stretching on a wide range of muscle groups (15 seconds per stretch). CG: Standard PE classes.	Recruitment: N/R IG1 Attrition Rate: 0% (12 to 12) IG2 Attrition Rate: 25.0% (12 to 9) CG Attrition Rate: 11.1% (9 to 8) IG1 & IG2 Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility (M_{diff}): (Toe-Touch Test) IG1: 6.9±4.9 IG2: 3.9±1.2 CG: 0.4±4.5 Dorsal-Lumbar Flexibility (M_{diff}): (Wall-Heel Distance) IG1: 13.5±8.6 IG2: 2.2±5.9 CG: 1.8±9.9 Trunk Flexibility (M_{diff}): (Deep Bending Test) IG1: 6.4±5.0 IG2: 3.1±2.4 CG: 1.6±2.9 Hamstring Flexibility (M_{diff}): (Leg Raise Test) IG1: 9.3±9.3 IG2: 7.4±11.4 CG: -0.3±7.3	Intergroup Difference (Toe-Touch Test): Post IG1* vs. Post CG Post IG2* vs. Post CG Post IG1* vs. Post IG2 Intergroup Difference (Wall-Heel Distance): Post IG1* vs. Post CG Post IG2 vs. Post CG (NS) Post IG1* vs. Post IG2 Intergroup Difference (Deep Bending Test): Post IG1* vs. Post CG Post IG2* vs. Post CG Post IG1* vs. Post IG2 Intergroup Difference (Leg Raise Test): Post IG1* vs. Post CG Post IG2* vs. Post CG Post IG1* vs. Post IG2
Becerra-Fernandez, 2016[22]	IG: *n* = 55 (16-17 years) CG: *n* = 53 (16-17 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions; missing an evaluation session.	Length: 8 weeks IG: 4 minutes, twice per week of hamstring stretches using a dynamic technique during warm-up and cooldown of PE classes (60 seconds per stretch). Detraining was performed for 4 weeks after the intervention. CG: Standard PE classes.	Recruitment: 100% (108 out of 108) IG Attrition Rate: 10.9% (55 to 49) CG Attrition Rate: 0% (53 to 53) IG Adherence Rate: >95% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 31.4±5.8 CG: 31.5±6.9 Post-Test: IG: 34.0±5.3 CG: 29.6±7.3	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG*** Pre CG*** vs. Post CG
Bohajar-Lax, 2015[32]	IG1: *n* = 30 (16-17 years) IG2: *n* = 29 (16-17 years) Inclusion Criteria: N/R Exclusion Criteria: Surgery on the spine or hamstring; diagnosed spinal abnormality.	Length: 5 weeks IG1: 5 minutes, twice per week of hamstring stretches using a static technique during warm-up of PE classes on consecutive days (20 seconds per stretch). IG2: 5 minutes, twice per week of hamstring stretches using a static technique during warm-up of PE classes on non-consecutive days (20 seconds per stretch).	Recruitment: N/R IG1 Attrition Rate: N/R IG2 Attrition Rate: N/R IG1 & IG2 Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility (M_{diff}): (Sit-and-Reach Test) Pre-Test: IG1: -1.4 ± 8.8 IG2: 3.4 ± 10.4 Post-Test: IG1: 0.8 ± 7.9 IG2: 5.7 ± 10.2	Intergroup Difference: Post IG1 vs. Post IG2 (NS) Intragroup Differences: Pre IG1 vs. Post IG1** Pre IG2 vs. Post IG2***

(continued)

Table 1. Characteristics of the Studies Included in the Systematic Review (continuation).

Author (Year)	Participants	Intervention and Control Groups	Responsive Outcomes	Flexibility Scores	Flexibility Differences
Coledam, 2012[16]	IG1: *n* = 15 (9.5±0.6 years) IG2: *n* = 16 (9.5±0.6 years) CG1: *n* = 15 (9.7±0.7 years) CG2: *n* = 15 (9.3±0.5 years) Inclusion Criteria: No participation in any kind of systematized physical training. Exclusion Criteria: Attendance rate of less than 85% for sessions.	Length: 12 weeks IG1 & IG2: 7 minutes of lower body stretches using a static technique during cooldown of PE classes. CG1 & CG2: Standard PE classes.	Recruitment: N/R IG1 & IG2 Attrition Rate: N/R CG1 & CG2 Attrition Rate: N/R IG & IG2 Adherence Rate: >85% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG1: 24.0±5.6 IG2: 24.7±6.7 CG1: 25.4±4.8 CG2: 25.5±6.1 Post-Test: IG1: 26.4±6.9 IG2: 27.9±6.3 CG1: 24.2±6.7 CG2: 26.2±5.6	Intragroup Differences: Pre IG1 vs. Post IG1* Pre IG2 vs. Post IG2*** Pre CG1 vs. Post CG1 (NS) Pre CG2 vs. Post CG2 (NS)
Gonzalez-Galvez, 2015[19]	IG: *n* = 39 (14.4±0.6 years) CG: *n* = 27 (14.0±0.5 years) Inclusion Criteria: Assertion that each student was free of musculoskeletal, neurological, cardiac, metabolic or rheumatic conditions. Exclusion Criteria: Prior history of spine pathologies/injuries or who had received previous treatment for back injuries; missing more than one session.	Length: 6 weeks IG: 55 minutes, twice per week of Pilates Method exercises. CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: N/R CG Attrition Rate: N/R IG Adherence Rate: 91.7% Adverse Events: N/R	Hamstring Flexibility (M_{diff}): (Sit-and-Reach Test) Pre-Test (Females): IG: 4.6±9.9 CG: 1.0±5.7 Post-Test (Females): IG: 8.5±8.4 CG: 1.1±7.3 Pre-Test (Males): IG: -2.2±8.5 CG: -8.9±5.8 Post-Test (Males): IG: 1.2±8.14 CG: -8.9±5.9	Intergroup Difference: Girls: Post IG** vs. Post CG Boys: Post IG** vs. Post CG Intragroup Differences: Girls: Pre IG vs. Post IG** Girls: Pre CG vs. Post CG (NS) Boys: Pre IG vs. Post IG** Boys: Pre CG vs. Post CG (NS)
Schawanke, 2016[17]	IG: *n* = 29 (7-17 years) CG: *n* = 32 (7-17 years) Inclusion Criteria: No participation in exercise program other than physical education classes or physical therapy treatment. Exclusion Criteria: No orthopedic disorders or history of orthopedic surgery.	Length: 16 weeks IG: 30 minutes, three times per week of stretching and strengthening exercises. CG: Usual care.	Recruitment: 47.3% (61 out of 129) IG Attrition Rate: 20.7% (29 to 23) CG Attrition Rate: 28.1% (32 to 23) IG Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test (Females): IG: 23.3±9.9 CG: 18.3±6.7 Post-Test (Females): IG: 28.8±7.3 CG: 20.2±6.0 Pre-Test (Males): IG: 20.4±7.1 CG: 15.6±7.6 Post-Test (Males): IG: 22.3±5.5 CG: 16.2±7.4	Intergroup Difference: Girls: Post IG* vs. Post CG Boys: Post IG** vs. Post CG Intragroup Differences: Girls: Pre IG vs. Post IG** Girls: Pre CG vs. Post CG (NS) Boys: Pre IG vs. Post IG (NS) Boys: Pre CG vs. Post CG (NS)
Mayorga-Vega, 2014[23]	IG: *n* = 22 (9.9±0.3 years) CG: *n* = 23 (9.9±0.3 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions; missing an evaluation session.	Length: 8 weeks IG: 5 minutes, twice per week of hamstring stretches using a static technique during cooldown of PE classes (20 seconds per stretch). Detraining was performed for 5 weeks after the intervention. CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: 0% (22 to 22) CG Attrition Rate: 0% (23 to 23) IG Adherence Rate: >90% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 17.1±5.6 CG: 14.2±4.2 Post-Test: IG: 18.6±5.7 CG: 14.6±4.1	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG*** Pre CG vs. Post CG (NS)

(continued)

Table 1. Characteristics of the Studies Included in the Systematic Review (continuation).

Author (Year)	Participants	Intervention and Control Groups	Responsive Outcomes	Flexibility Scores	Flexibility Differences
Mayorga-Vega, 2014[24]	IG: *n* = 22 (10.9±0.3 years) CG: *n* = 23 (10.9±0.3 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions.	Length: 8 weeks IG: 6 minutes, twice per week of hamstring/lumbar stretches using a static technique during cooldown of PE classes (20 seconds per stretch). Detraining was performed for 5 weeks after the intervention. CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: 0% (22 to 22) CG Attrition Rate: 0% (23 to 23) IG Adherence Rate: >95% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 15.7±7.0 CG: 13.4±8.5 Post-Test: IG: 18.2±7.7 CG: 13.1±8.5	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG*** Pre CG vs. Post CG (NS)
Mayorga-Vega, 2015[25]	IG1: *n* = 60 (12.7±0.7 years) IG2: *n* = 59 (12.7±0.6 years) CG: *n* = 61 (12.6±0.6 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions; incorrect performance of flexibility evaluation.	Length: 8 weeks IG1: 4 minutes, once per week of hamstring stretches using a static technique during cooldown of PE classes (30 seconds per stretch). IG2: 4 minutes, twice per week of hamstring stretches using a static technique during cooldown of PE classes (30 seconds per stretch). CG: Standard PE classes.	Recruitment: 100% (180 out of 180) IG1 Attrition Rate: 11.7% (60 to 53) IG2 Attrition Rate: 11.9% (59 to 52) CG Attrition Rate: 4.9% (61 to 58) IG1 & IG2 Adherence Rate: >90% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG1: 20.2±6.7 IG2: 20.7±7.7 CG: 20.4±7.0 Post-Test: IG1: 21.7±6.6 IG2: 22.6±8.2 CG: 20.7±7.4	Intergroup Difference: Post IG1** vs. Post CG Post IG2*** vs. Post CG Post IG1 vs. Post IG2 (NS) Intragroup Differences: Pre IG1 vs. Post IG1** Pre IG2 vs. Post IG2*** Pre CG vs. Post CG (NS)
Mayorga-Vega, 2016[26]	IG1: n = 51 (8.5±0.8 years) IG2: n = 51 (8.4±0.8 years) CG: n = 49 (8.4±0.6 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions; incorrect performance of flexibility evaluation.	Length: 9 weeks IG1: 4 minutes, twice per week of hamstring stretches using a static technique during cooldown of PE classes (30 seconds per stretch). Detraining was performed for 5 weeks after the intervention performing the same stretches for 4 minutes. IG2: 4 minutes, twice per week of hamstring stretches using a static technique during cooldown of PE classes (30 seconds per stretch). Detraining was performed for 5 weeks after the intervention performing a maintenance program for 1 minute. CG: Standard PE classes.	Recruitment: 100% (150 out of 150) IG1 Attrition Rate: 13.7% (51 to 44) IG2 Attrition Rate: 0% (51 to 51) CG Attrition Rate: 8.2% (49 to 45) IG1 & IG2 Adherence Rate: >90% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG1: 16.8±5.7 IG2: 16.8±5.5 CG: 15.3±5.2 Post-Test: IG1: 19.5±6.0 IG2: 19.1±5.1 CG: 15.4±4.9	Intergroup Difference: Post IG1** vs. Post CG Post IG2*** vs. Post CG Post IG1 vs. Post IG2 (NS) Intragroup Differences: Pre IG1 vs. Post IG1** Pre IG2 vs. Post IG2*** Pre CG vs. Post CG (NS)
Mayorga-Vega, 2017[27]	IG: *n* = 19 (9 years) CG: *n* = 18 (9 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions; incorrect performance of flexibility evaluation.	Length: 32 weeks IG: 3 minutes, once per week of hamstring stretches using a static technique during cooldown of PE classes (20 seconds per stretch). CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: 0% (19 to 19) CG Attrition Rate: 0% (18 to 18) IG Adherence Rate: >90% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 24.0±5.5 CG: 24.2±7.2 Post-Test: IG: 25.5±5.8 CG: 23.9±7.7	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG** Pre CG vs. Post CG (NS)

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Table 1. Characteristics of the Studies Included in the Systematic Review (continuation).

Author (Year)	Participants	Intervention and Control Groups	Responsive Outcomes	Flexibility Scores	Flexibility Differences
Merino-Marban, 2014[28]	IG: *n* = 23 (5.9±0.3 years) CG: *n* = 22 (5.9±0.3 years) Inclusion Criteria: No orthopedic disorders over the past six months. Exclusion Criteria: Attendance rate of less than 90% for sessions.	Length: 8 weeks IG: 1 minute, twice per week of hamstring stretches using a static technique during cooldown of traditional games (30 seconds per stretch). Detraining was performed for 5 weeks after the intervention. CG: Traditional games.	Recruitment: N/R IG Attrition Rate: 0% (23 to 23) CG Attrition Rate: 0% (22 to 22) IG Adherence Rate: >90% Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 16.4±4.9 CG: 16.9±5.0 Post-Test: IG: 18.8±5.8 CG: 16.9±4.9	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG*** Pre CG vs. Post CG (NS)
Sainz de Baranda, 2009[20]	IG: *n* = 26 (13.7±0.4 years) CG: *n* = 24 (13.7±0.4 years) Inclusion Criteria: N/R Exclusion Criteria: Prior history of spine pathologies.	Length: 31 weeks IG: Lower body stretches twice per week after warm-up for 5 minutes and after cooldown for 2 minutes during PE classes (15 seconds per stretch). CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: 0% (26 to 26) CG Attrition Rate: 0% (24 to 24) IG Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility: (Leg Raise Test) Pre-Test (Right Leg): IG: 79.7±7.0 CG: 79.2±12.7 Post-Test (Right Leg): IG: 87.3±5.5 CG: 77.3±8.0 Pre-Test (Left Leg): IG: 79.6±6.0 CG: 78.5±11.8 Post-Test (Left Leg): IG: 86.7±3.3 CG: 76.8±6.5	Intergroup Difference: Post IG*** vs. Post CG Intragroup Differences: Pre IG vs. Post IG*** Pre CG vs. Post CG (NS)
Rodriguez-García, 1999[29]	IG1: *n* = 23 (10.3±0.3 years) IG2: *n* = 23 (13.5±0.7 years) CG1: *n* = 18 (10.3±0.3 years) CG2: *n* = 13 (13.5±0.7 years) Inclusion Criteria: N/R Exclusion Criteria: N/R	Length: 32 weeks IG1 & IG2: Hamstring stretches twice per week after warm-up for 5 minutes and after cooldown for 2 minutes during PE classes. CG1 & CG2: Standard PE classes.	Recruitment: 92.8% (77 out of 83) IG1 & IG2 Attrition Rate: N/R CG1 & CG2 Attrition Rate: N/R IG1 & IG2 Adherence Rate: N/R Adverse Events: N/R		
Rodriguez-García, 2008[30]	IG1: *n* = 25 (10.3±0.3 years) IG2: *n* = 24 (13.5±0.7 years) CG1: *n* = 21 (10.3±0.3 years) CG2: n = 20 (13.5±0.7 years) Inclusion Criteria: No musculoskeletal disorders or lower-back pain. Exclusion Criteria: N/R	Length: 32 weeks IG1 & IG2: Hamstring stretches twice per week after warm-up for 3 minutes and after cooldown for 2 minutes during PE classes (20 seconds per stretch). CG1 & CG2: Standard PE classes.	Recruitment: N/R IG1 & IG2 Attrition Rate: N/R CG1 & CG2 Attrition Rate: N/R IG1 & IG2 Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility (M_{diff}): (Sit-and-Reach Test) Pre-Test: IG1: -0.7±6.1 IG2: -4.0±7.7 CG1: 0.4±8.5 CG2: -0.4±6.2 Post-Test: IG1: 1.3±7.8 IG2: 3.2±7.8 CG1: -3.9±9.9 CG2: -2.7±7.3	Intergroup Difference: Post IG1*** vs. Post CG1 Post IG2*** vs. Post CG2 Intragroup Differences: Pre IG1 vs. Post IG1 (NS) Pre IG2 vs. Post IG2*** Pre CG1*** vs. Post CG1 Pre CG2 vs. Post CG2 (NS)
Sanchez-Rivas, 2014[31]	IG: *n* = 22 (7.8±0.4 years) CG: *n* = 22 (7.9±0.5 years) Inclusion Criteria: Prior history of pathologies that could be aggravated. Exclusion Criteria: Missing an evaluation session or more than two sessions.	Length: 9 weeks IG: 3 minutes, twice per week of hamstring stretches using a static technique during cooldown of PE classes (20 seconds per stretch). CG: Standard PE classes.	Recruitment: N/R IG Attrition Rate: 0% (22 to 22) CG Attrition Rate: 0% (22 to 22) IG Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility: (Sit-and-Reach Test) Pre-Test: IG: 17.1±3.6 CG: 16.6±5.6 Post-Test: IG: 18.2±3.7 CG: 16.0±5.5	Intergroup Difference: Post IG** vs. Post CG

(continued)

Table 1. Characteristics of the Studies Included in the Systematic Review (continuation).

Author (Year)	Participants	Intervention and Control Groups	Responsive Outcomes	Flexibility Scores	Flexibility Differences
Santonja-Medina 2007[21]	IG1: *n* = 25 (10-11 years) IG2: *n* = 20 (10-11 years) CG: *n* = 18 (10-11 years) Inclusion Criteria: N/R Exclusion Criteria: N/R	Length: 31 weeks IG1: Hamstring stretches twice per week after warm-up for 3 minutes and after cooldown for 2 minutes during PE classes (20 seconds per stretch). IG2: Hamstring stretches four times per week after warm-up for 3 minutes and after cooldown for 2 minutes during PE classes and extracurricular physical activity (20 seconds per stretch). CG: Standard PE classes.	Recruitment: N/R IG1 Attrition Rate: 0% (25 to 25) IG2 Attrition Rate: 0% (20 to 20) CG Attrition Rate: 0% (18 to 18) IG1 & IG2 Adherence Rate: N/R Adverse Events: N/R	Hamstring Flexibility (Mdiff): (Leg Raise Test) Pre-Test (Right Leg): IG1: 77.7±12.0 IG2: 76.7±11.5 CG: 79.2±12.7 Post-Test (Right Leg): IG1: 86.7±7.5 IG2: 93.7±8.5 CG: 77.7±12.0 Pre-Test (Left Leg): IG1: 77.6±9.0 IG2: 76.6±10.2 CG: 78.5±11.8 Post-Test (Left Leg): IG1: 85.7±8.5 IG2: 93.5±5.0 CG: 76.4±9.5	Intergroup Difference: Post IG1*** vs. Post CG Post IG2*** vs. Post CG Post IG1 vs. Post IG2*** Intragroup Differences: Pre IG1 vs. Post IG1*** Pre IG2 vs. Post IG2*** Pre CG vs. Post CG (NS)

Note. Statistics are reported as means ± standard deviations unless otherwise specified; Mdiff: mean difference; N/R: not reported; NS: non-significant; IG: intervention group; CG: control group; PE: physical education.
*p < .05. **p < .01. ***p < .001

the stretching interventions lasted between 5 and 32 weeks (M = 15.3, SD = 2.7), with sessions lasting 1-55 minutes each (M = 10.4, SD = 2.9) and performed at a frequency of 1-4 times per week (M = 2.0, SD = 0.1).

Three of the included studies used a full stretching intervention as a replacement for the participants' physical education classes[17-19], whereas the remaining 14 studies incorporated the stretching intervention into the warm-up and/or cooldown of their physical education classes. Control groups were used in 16 out of 17 studies, including standard physical education classes (n = 14), traditional games (n = 1), and a usual care group (n = 1).

No major or minor adverse events were reported in any studies and the attrition rate was 7.1% across twelve studies, ranging between 0-25%. The remaining five studies did not report the attrition rate in the intervention group. Nine studies reported an adherence rate above 85%, while eight studies did not report adherence rates.

Quality appraisal

Quality assessment criteria for the 17 included studies can be found in (Table 2)[18] was evaluated as an RCT according to the PEDro scale, which was given a score of 5/10 and considered fair quality. The remaining 16 studies were evaluated as non-RCTs using the MINORS scale. The average score of the non-RCTs was 17.4 out of 24, with scores ranging from 15 to 21. Overall, this indicated that the included studies have moderate-to-high methodological quality.

Results of the individual studies

The included studies reported outcome data across five outcomes: Sit-and-Reach (SR) test (n = 13), Leg Raise (LR) test (n = 3), Toe-Touch (TT) test (n = 1), Wall-Heel Distance (n = 1), and Deep Bending test (n = 1).

In a comparison of active global stretching (4-10 minutes per stretch), analytical stretching (15 seconds per stretch), and standard physical education classes, the active global stretching group had significantly greater improvements in hamstring, trunk, and dorsal-lumbar flexibility compared to the other comparison groups[18]. The analytical stretching group also had significantly greater improvements in hamstring and trunk flexibility compared to standard physical education.

Intergroup differences were found for hamstring flexibility. All three studies using the LR test demonstrated significantly greater improvements for left and right legged hamstring flexibility in the stretching intervention when compared to control conditions[18,20,21]. Similarly, significant greater improvements in hamstring flexibility were observed between intervention and control groups on the Sit-and-Reach test for all 11 studies that reported intergroup differences[17,19,22-28,30,31].

Two studies examined intragroup differences between pre- and post-intervention scores in male and female participants separately[17,19]. Although female participants showed significant post-treatment improvements in hamstring flexibility for both studies, male participants only reported significant improvements in one of the two studies.

Results of the meta-analysis

A total of 761 participants were included in the meta-analysis for hamstring flexibility using the SR and TT tests (Figure 2). A significant medium effect was found in favour of the intervention groups (random effects model SMD = 0.46; 95% CI = 0.22, 0.70; I-squared heterogeneity = 56.9%). The meta-analysis for the LR test resulted in a significant and large effect in favour of the intervention groups (n = 113; fixed effect model SMD = 1.22; 95% CI = 0.80, 1.64; I-squared heterogeneity = 0%). Data was pooled from 874 participants when the analysis included SR,

Table 2. Quality Assessment.

PEDro scale		1	2	3	4	5	6	7	8	9	10	11	Total
Useros-García (2010)[18]		Y*	Y	N	N	N	N	Y	Y	N	Y	Y	5 / 10
MINORS scale	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
Becerra-Fernandez (2016)[22]	2	2	2	1	0	2	2	0	2	2	2	2	19 / 24
Bohajar-Lax (2015)[32]	2	2	2	1	0	2	0	0	0	2	2	2	15 / 24
Coledam (2012)[16]	2	2	2	1	0	2	2	2	2	2	2	2	21 / 24
Gonzalez-Galvez (2015)[19]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Schwanke (2016)[17]	2	2	2	1	0	2	2	2	2	2	1	2	20 / 24
Mayorga-Vega (2014)[23]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Mayorga-Vega (2014)[24]	2	2	2	1	0	2	2	0	2	2	2	2	19 / 24
Mayorga-Vega (2015)[25]	2	2	2	1	0	2	2	0	2	2	2	2	19 / 24
Mayorga-Vega (2016)[26]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Mayorga-Vega (2017)[27]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Merino-Marban (2014)[28]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Sainz de Baranda (2009)[20]	2	2	2	1	0	2	2	0	2	2	0	2	17 / 24
Rodriguez-García (1999)[29]	2	0	2	1	0	2	2	0	2	2	0	2	15 / 24
Rodriguez-García (2008)[30]	2	0	2	1	0	2	0	0	2	2	2	2	15 / 24
Sanchez-Rivas (2014)[31]	2	2	2	1	0	2	0	0	2	2	2	2	17 / 24
Santonja-Medina (2007)[21]	2	0	2	1	0	2	2	0	2	2	2	2	17 / 24

Note. Y = yes; N = no.
*Not included in total score.

TT and LR tests, which found a significant moderate effect in favour of the intervention groups (random effects model SMD = 0.58; 95% CI = 0.32, 0.83; I-squared heterogeneity = 66.7%).

Discussion

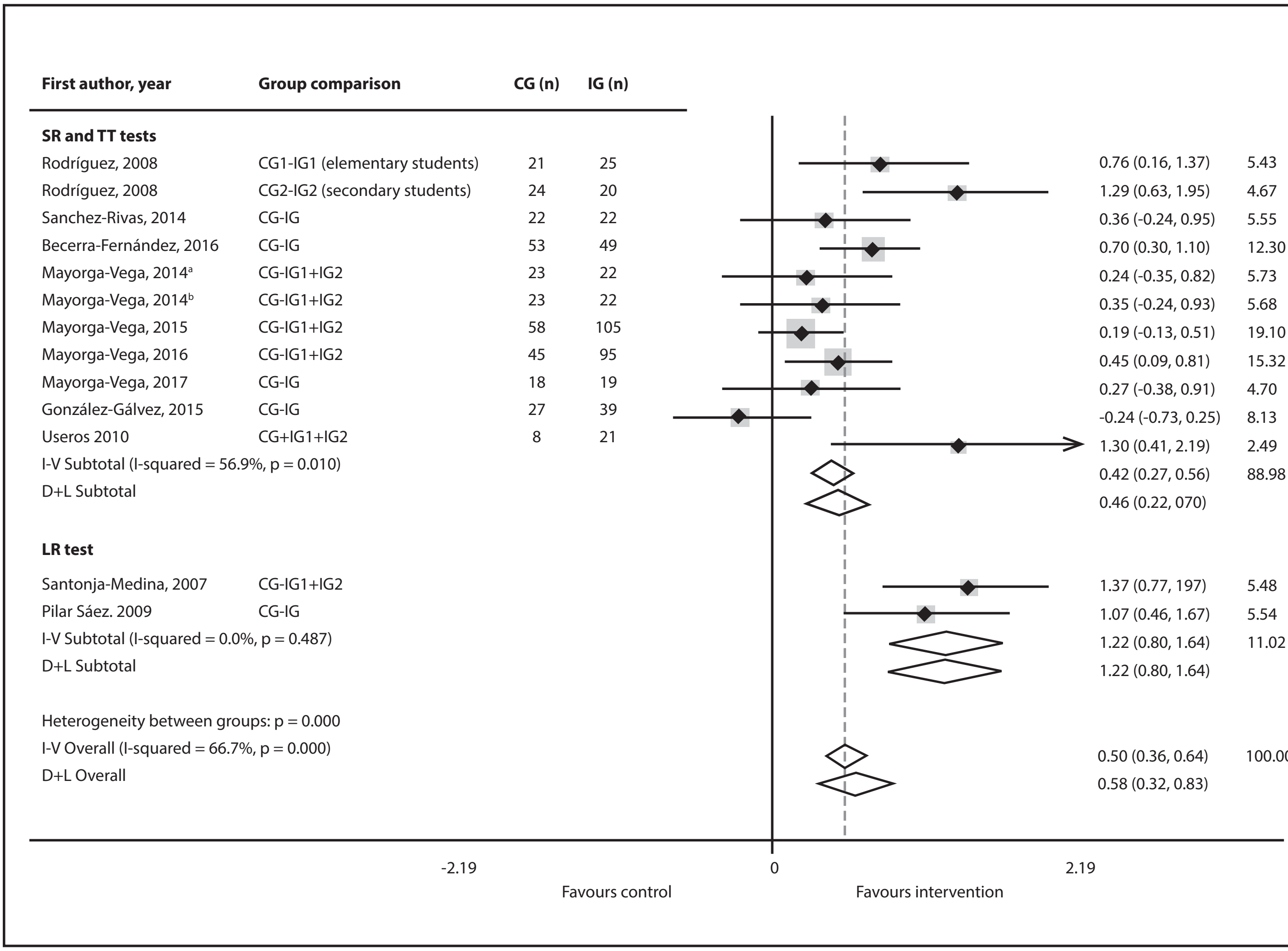
In the present research, the existing scientific evidence on the effects of stretching interventions carried out during PE classes on the flexibility of school students were synthesized and summarized. After a thorough investigation of the literature, a published review with a similar topic was found[33]. However, this work was closer to a narrative review than to a systematic review, since no methodological quality assessment of the included studies was carried out. Moreover, no meta-analysis was performed to quantitatively assess the benefits of stretching interventions on flexibility in school children. Instead, this work was specifically focused on a unique variable (hamstring extensibility) and in a specific population (primary children). Therefore, the present review provides a greater foundation of evidence for PE teachers who wish to improve the flexibility level of their students during PE classes.

Notably, the current review identified a substantial number of investigations published on the research topic that have been shown to possess acceptable methodological quality. In this regard, it should be highlighted that some of the investigations reviewed were described by the authors as cluster randomize trials. However, given the small number of schools included these studies (generally only two) and the low number of participants considered eligible for each cluster, they were appropriately treated as comparative investigations.

According to the results of the included studies, stretching interventions performed during PE classes are a feasible strategy for improving flexibility in all educational levels. This includes preschool, primary and secondary (high school) students. Even interventions involving just a few minutes of stretching during warm-up and/or cooldown of PE classes seemed to be effective. These observations indicate that flexibility can be gradually improved as long as it is progressively continued. This is an interesting finding since schools provide an ideal setting for children to maintain their flexibility levels throughout their schooling, which tend to gradually decrease with age[34].

Most importantly, the current meta-analysis focused on hamstring extensibility and included a large sample of children tested on three flexibility assessments procedures[35]. This supports the implementation of stretching as key element of PE sessions, since reduced hamstring flexibility is a common clinical concern in children and adolescents that can often lead to low-back pain, postural problems and a higher risk of muscle injury[36]. However, it should be noted that the SR was a field-based test used for assessing hamstring extensibility on a majority of the investigations, and it has been suggested that the score of this test is strongly influenced by low back (pelvic tilt and lumbar spine) range of motion[37]. Therefore, it is possible that some of these interventions

Figure 2. Meta-analysis.



could have a greater impact on the pelvic and lumbar spine than on the hamstring muscles.

Despite these findings, there are certain characteristics of the included studies that should be mentioned, since they may potentially affect the interpretation of the results. Firstly, most of the investigations did not gather information regarding students' participation on exercise training or sporting activities. This is potentially a confounding factor that could have influenced the obtained results. Secondly, only two investigations reported separate outcome data for each sex, resulting in mixed findings. Therefore, it is not clear whether the effects of the stretching interventions were different between boys and girls. It has been noted that sex has a substantial influence on flexibility levels during school years, with girls generally outperforming boys[38]. In particular, it has been proposed that females have less passive tissue resistance to angular motion, resulting in females having greater knee flexor extensibility and less passive knee flexor stiffness compared to males[39]. It is therefore plausible that boys and girls may respond differently to stretching interventions. Further research is needed to investigate these flexibility differences between school-aged boys and girls.

In summary, the present review provides valuable information regarding the beneficial effects of implementing stretching interventions during PE classes. It is important to note, however, that there are some inherent limitations that should be acknowledged in the current literature. In particular, there are very few RCTs that have been conducted on this topic, research has not considered sex as a potential moderating factor on the efficacy of stretching interventions, and that most investigations only focus on hamstring extensibility. In addition, a considerable amount of studies administered the "sit and reach" test for this purpose. In this regard, it should be acknowledged that this is a linear test whose results might be affected by anthropometric factors and range of motion of the lumbar spine[40]. These factors limit the applicability of the scientific evidence provided in the current review. In addition, some limitations inherent to this research design such us language restrictions and not having reviewed the grey literature, should also be acknowledged.

Conclusion

This review provides preliminary scientific evidence indicating that flexibility levels can be improved through the incorporation of stretching interventions during PE classes. Further research is needed on the effects of such interventions on trunk and upper body flexibility. Future studies should take into account exercise and sport performed outside the school setting, as well as the influence of sex as potential confounding factors.

Implications for school health

Physical education (PE) programs are evolving from a traditional skill-centered model to a health-centered model that focuses on improving fitness. Consequently, activities aimed to increase health-related physical fitness should be performed during PE class, including stretching routines, since flexibility is a key health-related physical fitness component. Flexibility training is not often included in the physical activity guidelines for the general population[11]. However, for active people who are motivated towards exercising, the inclusion of stretching routines is considered an important strategy, as it reduces muscle injuries and increases joint range of motion[41]. One of the goals of PE is the development of positive attitudes towards active lifestyles among students. Thus, including flexibility training during PE class is an approach that can assist in achieving this goal.

Physical education policies have received increased attention as a means for improving physical activity levels. In this regard, performing activities such ball play, playing games, gymnastics, dance or fitness during PE class, it is considered a useful strategy for helping to reach children the amount of physical activity recommended[42]. The results of our study shows that if PE teachers decide to include stretching routines, even if is only for a short period of time (i.e. before and after the performance of these activities), they would increase the potential contribution that PE can make for meeting public health goals.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Ortega FB, Ruiz JR, Castillo MJ, Sjöström M. Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes* .2008; 32:1-11.
2. Pate RR, Oria M, Pillsbury L. *Fitness measures and health outcomes in youth*. Washington DC: National Academies Press. 2012;259.
3. Coelho JJ, Graciosa MD, de Medeiros DL, Pacheco SC, da Costa LM, Ries LG, *et al.* Influence of flexibility and gender on the posture of school children. *Rev Paul Pediatr.*2014; 32:223–8.
4. Kemmochi M, Sasaki S, Ichimura S. Association between reduced trunk flexibility in children and lumbar stress fractures. *J Orthop.*2018;15:122-7.
5. Sjolie, AN. Low-back pain in adolescents is associated with poor hip mobility and high body mass index. *Scand J Med Sci Sports*. 2004;14:168-75.
6. Lopes L, Povoas S, Mota J, Okely D, Coelho-e-Silva MJ, Cliff DP, *et al.* Flexibility is associated with motor competence in schoolchildren. *Scand J Med Sci Sports.*2017; 27:1806-13.
7. Rodrigues LP, Luz C, Cordovil R, Bezerra P, Silva B, Camões M, *et al.* Normative values of the motor competence assessment (MCA) from 3 to 23 years of age. *J Sci Med Sports*. 2019;22:1038-43.
8. Zhang C, Yang Y. Can policy alone stop decline of children and youth fitness?. *Res Q Exerc Sport*. 2017;88:9-14.
9. Stodden D, Sacko R, Nesbitt D. A review of the promotion of fitness measures and health outcomes in youth. *Am J Lifestyle Med.* 2015;11:232-42.
10. Venckunas T, Emeljanovas A, Mieziene B, Volbekiene V. Secular trends in physical fitness and body size in Lithuanian children and adolescents between 1992 and 2012. *J Epidemiol Community Health*. 2017;71:181-7.
11. Piercy KL, Troiano RP, Ballard RM, Carlson RM, Fulton JE, Galuska DA, *et al.* The physical activity guidelines for americans. *JAMA*.2018;320:2020-8.
12. Hills AP, Dengel DR, Lubans DR. Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog Cardiovasc Dis*. 2015; 57:368-74.
13. Foley NC, Teasell RW, Bhogal SK, Speechley MR. Stroke rehabilitation evidence-based review: methodology. *Top Stroke Rehabil.* 2003;10:1-7.
14. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): Development and validation of a new instrument. *ANZ J Surg*. 2003;73:712-6.
15. Valentine JC, Pigott TD. Rothstein HR. How many studies do you need? *J Educ Behav Stat.* 2010;35:215-47.
16. Coledam DHC, De Arruga GA, de Oliveira AR.Effects of an exercise program on childrens flexibility and vertical jump performance. *Motr Rev Educ Fis*. 2012;18:515-25.
17. Schawanke NL,Pohl HH,Reuter CP,Borges TS, de Souza S,Burgos MS. Differences in body posture, strength and flexibility in schoolchildren with overweight and obesity: A quasi-experimental study. *Man Ther*. 2016;22:138-44.
18. Useros García P, Campos AM. Estiramientos analíticos y stretching global activo en las clases de educación física. *Fisiot*. 2011;33:70-8.
19. González-Galvez N, Carrasco PM, Marcos PP, de Souza VR, Feito Y .Effects of a pilates school program on hamstrings flexibility of adolescents. *Rev Bras Med Sporte*. 2015;2:302-7.
20. Sainz de Baranda P. El trabajo de la flexibilidad en educación física: Programa de intervención. *CCD*. 2009;5:33-8.
21. Santonja-Medina F, Sainz de Baranda P, Rodriguez-García PL, López-Miñarro PA, Canteras Jordan M. Effects of frequency of static stretching on straight-leg raise in elementary school children. *J Sports Med Phys Fitness*. 2007;47:304-8.
22. Becerra Fernández C, Merino-Marban R, Mayorga-Vega D. Effect of a physical education-based dynamic stretching program on hamstring extensibility in female high-school students .Kinesiology.2016;48:258-66.
23. Mayorga-Vega D, Merino-Marban R, Vera EF, Viciana J. Effect of a short-term physical education –based flexibility program on hamstring and lumbar extensibility and its posterior reduction in primary schoolchildren. *Kinesiology.* 2014;46:227-33.
24. Mayorga-Vega D, Merino-Marban R, Sanchez RE, Viciana J. Effect of a short-term static stretching training program followed by five weeks of detraining on hamstring extensibility in children aged 9-10 years. *JPES*. 2014;14:355-9.
25. Mayorga-Vega D, Merino-Marban R, Real J, Viciana J. A physical education-based stretching program performed once a week also improves hamstring extensibility in schoolchildren: a cluster-randomized controlled trial. *Nutr Hosp.* 2015;32:1715-21.
26. Mayorga-Vega D, Merino-Marban R, Manzano LJ, Blanco H, Viciana J. Effects of a stretching development and maintenance program on hamstring extensibility in schoolchildren: a cluster-randomized controlled trial. *J Sports Sci Med*. 2016;15:65-74.
27. Mayorga-Vega D, Merino-Margan R, Redondo MF, Viciana J. Effect of a one-session-per-week physical education-based stretching program on hamstring extensibility in schoolchildren. *Kinesiology*. 2017;49:101-8.
28. Merino-Marban R, Mayorga-Vega D, Viciana J. Effect of a physical education-based stretching programme on sit-and-reach score and its posterior reduction in elementary schoolchildren. *Eur Phys Educ Rev.* 2014:1-10.
29. Rodriquez García PL, Santonja Medina F, Canteras Jordana M, Delgado Férnandez M, Fernández Piñera J, Balsalobre MARÍN j. Mejora de la extensibilidad isquiosural tras un programa escolar de estiramientos. *Selección*. 1999;8:157-64.
30. Rodriguez García PL,Santonja Medina F, Lopez Miñarro P, Sainz de Baranda P,Yuste JL.Effect of physical education stretching programme on sit-and reach score in schoolchildren. *Sci Sport*. 2008;23:170-5.
31. Sanchez Rivas E, Mayorga-Vega D, Fernadez Rodriguez E, Merino-Marban R. Effect of a hamstring stretching programme during physical education lessions in primary education. *J Sport Health Res.* 2014;6:159-68.
32. Bohajar-Lax A, Vaquero Cristobal R, Espejo-Antúnez L, López-Miñarro PA. Efecto de un programa de estiramiento de la musculatura isquiosural sobre la extensibilidad isquiosural en escolares adolescentes :influencia de la distribución semanal de las sesiones. *Nutr Hosp.* 2015;32:1241-5

33. Soriano FB, Alacid F. Flexibility programs and exercises within physical education classes for schoolchildren and their effect on the improvement of hamstring extensibility: A Systematic review. *MH Salud*. 2018;15:1-11.
34. Mckay MJ, Baldwin JN, Ferreira P, Simic M, Vanicek N,Burs J, *et al.* Normative references values strength and flexibility of 1,000 children and adults. *Neurology.* 2017;88:36-43.
35. Mayorga-Vega D, Merino-Marban R, Viciana J. Criterion –related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: a Meta-Analysis. *J Sports Sci Med*. 2014;13:1-14.
36. Czaprowski D, Leszczewska J, Kolwicz A, Pawlowska P, Kedra A, Janusz P, *et al.* The comparison of the effects of three physiotherapy techniques on hamstring flexibility in children: A prospective, randomized ,single-blind study. *PLoS One.* 2013;8:e72026.
37. Muyor JM, Zemkova E, Stefanikova G, Kotyra M. Concurrent validity of clinical tests for measuring hamstring flexibility in school age children. *Int J Spòrts Med*. 2014;35:664-9.
38. Tomkinson GR, Carver KD, Atkinson F, Daniell ND, Lewis LK,Fitzgerakd JS, *et al*. European normative values for physical fitness in children and adolescents aged 9-17 years:results from 2 779 165 eurofit performances representing 30 countries. B*r J Sports Med*. 2018;55:1445-56.
39. Blackburn JT, Riemann BL, Padua DA, Guskiewicz KM. Sex comparison of extensibility, passive, and active stiff Ness of the knee flexors. *Clin Biomech.* 2004;19:36-43.
40. López-Miñarro PA, García Ibarra A, Rodríguez García PL. Comparison between sit-and-reach tests for measuring hamstring muscle extensibility. *Apunts Educ Fís Deporte*. 2010;99:56-64.
41. Behm DG, Blazevich AJ, Kay AD, McHug M. Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. *Appl physiol nutr and metab*. 2015;41:1-11.
42. Fröberg A, Raustorp A, Pagel P, Larsson C, Boldemann C. Levels of physical activity during physical education lessons in Sweden. *Acta Pediatr.* 2017;106:135-41.