Influence of total stretching volume on hamstring muscle flexibility in Secondary students

Influencia del volumen total de estiramiento en la flexibilidad de la musculatura isquiosural en estudiantes de Educación Secundaria

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Abstract

Introduction: Flexibility is an essential component of physical fitness, particularly relevant during adolescence, a period during which lifestyle habits are consolidated and may influence long-term musculoskeletal health and physical performance.
Objective: The aim of this study was to examine the effects of two passive stretching programs of different durations on hamstring flexibility in secondary education students, while ensuring equivalence in the total stretching volume.
Methodology: A quasi-experimental design was used with three groups: one performing passive stretching with 60-second sets, another with 20-second sets, and a control group. The intervention lasted 10 weeks and was carried out during regular Physical Education sessions. Flexibility was assessed using the Wells and Dillon sit-and-reach test.
Results: Significant improvements in hamstring flexibility were observed in both intervention groups compared with the control group. Although the 60-second protocol showed a tendency to produce greater gains, the differences between the experimental groups did not reach statistical significance.
Discussion: These findings align with previous evidence highlighting total stretching volume as the key determinant of flexibility improvements, regardless of the duration of each individual set. They also support the feasibility of implementing passive stretching programs in educational contexts as effective and time-efficient strategies.
Conclusions: Passive stretching programs can be considered a practical and beneficial tool for improving hamstring flexibility in adolescents, and their inclusion in Physical Education lessons contributes to the promotion of health and physical development.

Keywords

Adolescents; flexibility; hamstring; passive stretching; Physical Education.

Resumen

Introducción: La flexibilidad es un componente fundamental de la condición física, especialmente relevante durante la adolescencia, etapa en la que se consolidan hábitos de vida que pueden influir en la salud musculoesquelética y en el rendimiento físico a largo plazo.
Objetivo: El objetivo de este estudio fue examinar los efectos de dos programas de estiramiento pasivo de diferente duración sobre la flexibilidad de la musculatura isquiosural en estudiantes de Educación Secundaria, garantizando la equivalencia en el volumen total de estiramiento.
Metodología: Se empleó un diseño cuasi-experimental con tres grupos: uno realizó estiramientos pasivos con series de 60 segundos, otro con series de 20 segundos y un grupo control. La intervención tuvo una duración de 10 semanas y se aplicó durante las clases de Educación Física. La flexibilidad se evaluó mediante el test de Wells y Dillon.
Resultados: Se observaron mejoras significativas en la flexibilidad de la musculatura isquiosural en ambos grupos de intervención en comparación con el grupo control. Aunque el protocolo de 60 segundos tendió a producir mayores ganancias, las diferencias entre los grupos experimentales no alcanzaron significación estadística.
Discusión: Estos hallazgos coinciden con evidencias previas que señalan el volumen total de estiramiento como el factor determinante en la mejora de la flexibilidad, independientemente de la duración de cada serie. Asimismo, respaldan la viabilidad de implementar programas de estiramiento pasivo en contextos escolares como estrategias eficaces y eficientes en términos de tiempo.
Conclusiones: Los programas de estiramiento pasivo pueden considerarse una herramienta práctica y beneficiosa para mejorar la flexibilidad de la musculatura isquiosural en adolescentes, y su inclusión en las clases de Educación Física contribuye a la promoción de la salud y al desarrollo físico del alumnado.

Palabras clave

Adolescentes; Educación Física; estiramiento pasivo; flexibilidad; isquiosurales.

Introduction

Flexibility is a fundamental component of physical fitness and overall health, particularly during adolescence, a critical period for establishing and consolidating lifelong physical activity habits (Alacid & Soriano-Férriz, 2018; Palanao et al., 2025). Contemporary lifestyles, characterized by sedentary behavior, lead to increased muscle stiffness and decreased range of motion, thereby compromising the efficient execution of daily movements (Da Costa et al., 2022; Kett et al., 2021; López-Miñarro et al., 2012).

Among the muscle groups affected, the hamstrings are especially relevant due to their role in hip and knee mobility, postural maintenance, and biomechanical efficiency. Several studies have shown that reduced hamstring extensibility compromises movement efficiency and increases fatigue, which is associated with a higher risk of muscle injuries, postural deviations, and functional limitations that may extend into adulthood (Becerra-Fernández et al., 2020; Pérez Vigo et al., 2022).

Since adolescence is a key period for establishing lasting habits, interventions aimed at improving flexibility may provide long-term benefits, not only in terms of physical performance but also in preventing chronic diseases associated with a sedentary lifestyle, such as obesity, cardiovascular diseases, and type 2 diabetes (Araujo et al., 2024; Behm et al., 2016). Adolescents who regularly engage in stretching routines are more likely to maintain flexibility into adulthood, thereby reducing the risk of injuries, improving mobility, and enhancing quality of life (Becerra-Fernández et al., 2020; Pérez Vigo, 2022). These considerations highlight the importance of incorporating appropriate guidance and supervision to maximize safety and effectiveness.

School-based physical education programs provide an ideal context for addressing hamstring flexibility deficits. Among the different approaches, passive stretching interventions have proven to be particularly effective in improving extensibility when adapted to the individual needs of students, the duration of each stretch, and the total volume of stretching within a session (Becerra-Fernández et al., 2020; Mayorga-Vega et al., 2015; van Rensburg & Coetzee, 2014).

Furthermore, integrating passive stretching into physical education curricula also addresses the practical constraints of schools. Short and efficient protocols, in which total stretching volume is prioritized over the duration of individual stretches, allow teachers to implement effective interventions within regular class periods while maintaining student participation and adherence. Research indicates that when total stretching volume is equal, both longer and shorter repetitions produce comparable improvements in flexibility. This highlights the potential of designing flexible programs that can be adapted to different educational contexts and schedules (Becerra-Fernández et al., 2020; van Rensburg & Coetzee, 2014).

Based on this evidence, the present study aimed to analyze the influence of two passive stretching protocols, EP-60 and EP-20, on hamstring extensibility in secondary school students. Specifically, it seeks to determine how these programs affect flexibility adaptations when the total stretching volume is constant, providing practical insights for the design of time-efficient, evidence-based interventions in physical education.

It is hypothesized that passive stretching will produce positive effects on hamstring extensibility and that the improvements will be similar when the total stretching volume is the same (three minutes), regardless of whether individual repetitions are performed for one minute or twenty seconds. In this way, the study supports the integration of structured flexibility routines into school curricula and reinforces the importance of promoting physical activity habits during adolescence and beyond, thereby improving musculoskeletal health, functional mobility, and injury prevention across the lifespan.

Method

Participants

One hundred and eighty students aged between 15 and 18 years old were invited to participate in this study. They were recruited from Antonio Machado Institute of Secondary Education (Alcalá de Henares, Spain). Inclusion criteria were: a) being a student aged 15-18 years, b) not having any conditions that could alter the results or be worsened by the stretching program. Exclusion criteria were: a) absence

from the evaluation test. A minimum of 90% of attendance was required. Sixteen students did not meet the inclusion criteria, and the legal guardians of 22 students refused to sign the consent form. Therefore 159 students were enrolled in the study and randomly distributed into EP-60, EP-20, and CG. All the participants signed a consent form before starting the trial, or, in the case of minors, their legal guardians.

Procedure

Design

This study was based on a quasi-experimental design with randomized group assignment. Students from the third and fourth-year Secondary Education were randomly allocated to one of three groups: a 60-second passive stretching program (EP-60, n=53), a 20-second passive stretching program (EP-20, n=53) and a control group (CG; n = 53). Both exercise programs were implemented over a 10-week period. The trial was managed by the Antonio Machado Secondary School (Alcalá de Henares, Spain) and was approved by the University of Almería Ethics Committee. The trial design followed CONSORT guidelines.

Randomization was performed by cluster (class group). Each class was assigned an identification number to allocate them to the respective groups. Three groups were formed: the EP-60 group, which carried out the 60-second passive stretching program; the EP-20 group, which carried out the 20-second passive stretching program; and the control group (CG), which did not receive any treatment. Only those responsible for the measurements and statistical analyses were blinded to group allocation due to the difficulty of blinding the participants and teachers leading the programs.

Flexibility program

The experiment was conducted for 10 weeks, during which each experimental group performed stretching twice per week during the cool-down phase of the Physical Education sessions. The stretches were led by the teacher of the respective group. Participants in the EP-60 group performed three sets of 60-second passive static stretches, while the EP-20 group performed nine sets of 20-second passive static stretches. Thus, the total volume was similar in both groups. Students were instructed to stretch until a mild tension was felt, but avoiding pain. Furthermore, they were guided to gradually reach the posture and, once attained, to hold it for the prescribed duration. Participants were also required to maintain the natural physiological curvature of the spine during execution. To ensure the external validity of the study, all groups were allowed to continue with their usual physical activity.

Wells and Dillon sit-and-reach test

Hamstring flexibility was assessed using the Wells and Dillon sit-and-reach test (Wells & Dillon, 1952; Castro-Piñero et al., 2009; Mayorga-Vega et al., 2014). For the administration of the test, a standardized wooden box measuring 30 cm in height was used, with a millimeter ruler fixed on the top surface. The reference value of "0 cm" was established at the level of the plantar surface of the feet, so that positive scores indicated that the student reached beyond the toes, whereas negative scores indicated that the toes were not reached. Each participant was assessed barefoot, seated on the floor with legs fully extended and the soles of the feet placed against the front panel of the box. From this position, and while maintaining knee extension, the participant bent the trunk forward slowly and progressively, with arms extended and hands overlapping, attempting to reach the greatest possible distance along the ruler. Two trials were performed, and the highest score (in centimeters) was recorded for analysis. To ensure the reliability of the data, a practical demonstration and one familiarization trial were provided the week before the test. A member of the research team supervised all administrations to guarantee correct execution and measurement validity.

Data analysis

Statistical analysis was performed using the statistical package Jamovi (Jamovi Project, 2025) for Mac. After analyzing the normality of variables (Kolmogorov-Smirnov test), one-way ANOVA was used to analyze the pretest measures. The post hoc test was evaluated for statistical significance (Bonferroni for parametric and Mann-Whitney U test for nonparametric variables). Repeated measures analysis of variance (ANCOVA) was adopted to investigate the interaction between groups and time. Baseline and gender were included as a covariates. Student's t-test for paired sample was used to evaluate variables

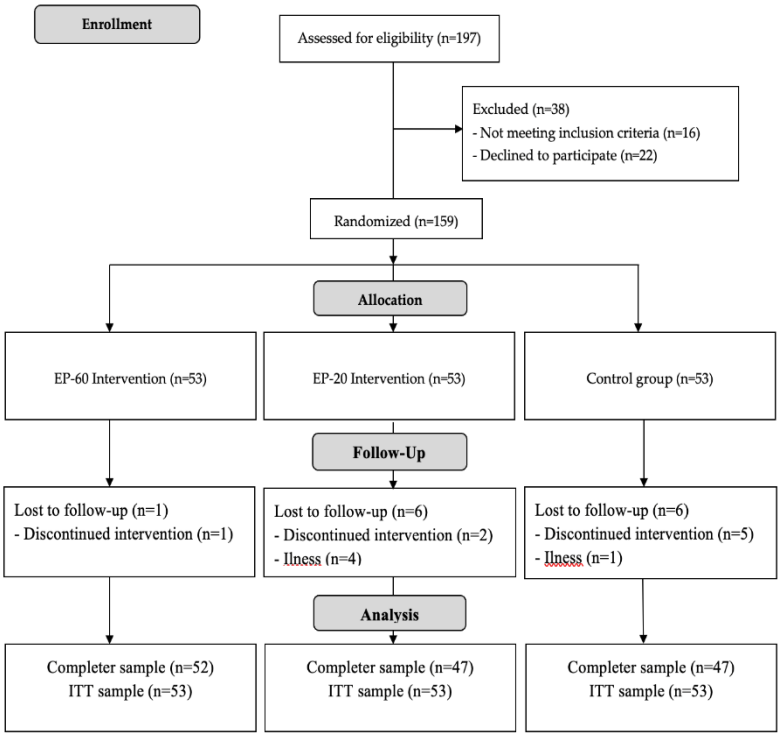
within groups. The standardized mean differences (Cohen's d -ES-) between pre- and post-testing and between groups (EP-60, EP-20 and CG) were calculated with the 95% confidence intervals (Hopkins et al., 2009). Statistical significance was set at p≤0.05.

Results

The primary outcome measures of this study were to determine the effect of two different passive stretching programs (EP-60 and EP-20) on muscle extensibility in secondary school students, as well as to compare changes in the Wells and Dillon test between the EP-60, EP-20 and control group.

A total of 159 participants were initially enrolled in the study and included in the analysis according to the intention-to-treat principle. Of these, 146 participants completed the intervention and were included in the final evaluation (EP-60: n = 52; EP-20: n = 47; CG: n = 47). Figure 1 illustrates the participant flow throughout the protocol. The period of recruitment was from March to April 2021. The trial ended in June 2021. Baseline characteristics of the participants are shown in Table 1.

Figure 1. Flow diagram of the progress of the randomized trial



Source: Own elaboration

Table 1. Characteristics at baseline (n=159)

Variable	n	Mean ± SD	Min	Max	*p*
Age (years)					
EP-60	53	16.24±1.07	15	18	
EP-20	53	15.96±1.03	15	18	<.001*
CG	53	16.37±37	15	18	
Weight (kg.)					
EP-60	53	56.56±10.05	45.0	80.0	
EP-20	53	61.59±10,07	45.0	88.6	0.534
CG	53	61.96±13.01	43.0	98.4	
Height (cm)					
EP-60	53	167.03±5.45	155	178	
EP-20	53	167.35±8.21	147	186	<.001*
CG	53	165±9.2	151	186	
BMI (Kg/m^2)					
EP-60	53	20.23±3.11	15.3	25.4	

EP-20	53	21.93±2.93	16.7	31.8	<.001*
CG	53	22.40±3.68	16.8	31.6	
Sit-and-reach test (cm)					
EP-60	53	17.6±7.64	3	33	
EP-20	53	12.8±12.44	-19	32	<0.039*
CG	53	10.2±14.59	-15	50	

*Significant differences, p< .05
Note: EP-60 – 60-second passive stretch program, EP-20 – 20-second passive stretch program, CG – Control Group, BMI – Body Mass Index

The results of the interactions between groups are shown in Table 2. After 10 weeks, both stretching interventions (EP-60 and EP-20) produced significant improvements in the Wells and Dillon sit-and-reach test. These gains were accompanied by small-to-moderate effect sizes, indicating meaningful changes in muscle extensibility. In contrast, the control group showed a slight decrease in performance over the same period.

Table 2. Intragroup differences in EP-60, EP-20, and CG

Variable	PRE	POST	*p*	95% CI for MD		Cohen's d
	Average DT	Average DT		Lower	Upper	
EP-60	17.57 ± 7.64	20.15 ± 7.86	<.001*	-3.11	-2.06	0.33
EP-20	12.85 ± 12.44	16.83 ± 10.47	<.001*	-5.05	-2.92	0.32
CG	10.17 ± 14.59	9.45 ± 15.45	0.021*	0.114	1.32	0.05

*Significant differences, p< .05
Nota: Nota: SD – Standard deviation, EP-60 – 60-second passive stretch program, EP-20 – 20-second passive stretch program, CG – Control Group

The ANCOVA results (Table 3) confirmed significant group-by-time interactions, with both experimental groups outperforming the control group. Post-hoc analyses revealed greater increases in flexibility in EP-60 compared with CG and in EP-20 compared with CG, whereas the difference between EP-60 and EP-20 was not statistically significant.

Table 3. ANCOVA interactions on EP-60, EP-20 and CG

Group	Increment			ANCOVA interactions (F, *p*, ES η^2)					
	n	Mean	SD	Training x Group			Training x Baseline		
				F	*p*	ES η^2	F	*p*	ES η^2
EP-60	53	20.15	7.86						
EP-20	53	16.83	10.47	11.6	<.001[1,2]	0.13	43.5	<.001[1,2]	0.35
CG	53	9.45	15.45						

*Significant differences, p< .05., [1] denotes significant differences in EP-60 compared to CG, [2] denotes significant differences in EP-20 compared to CG
Nota: SD – Standard deviation, EP-60 – 60-second passive stretch program, EP-20 – 20-second passive stretch program, CG – Control Group

Discussion

The primary finding of this study was that 10 weeks of passive stretching programs, whether performed in 60-second sets (EP-60) or 20-second sets (EP-20), significantly improved hamstring flexibility among secondary school students. Both protocols produced similar adaptations when total stretching volume was equivalent, supporting the notion that accumulated stretching volume is a stronger determinant of flexibility improvements than the duration of individual stretches (Konrad et al., 2024; Mayorga-Vega et al., 2015; Merino-Marbán et al., 2015). These results are consistent with previous school-based research that demonstrated meaningful flexibility gains when programs were structured and applied systematically (Mayorga-Vega et al., 2015; Merino-Marbán et al., 2025; Rodríguez et al., 2008).

Both experimental groups achieved greater improvements in the Wells and Dillon sit-and-reach test compared with the control group, confirming the effectiveness of passive stretching during adolescence. Although the EP-60 group showed slightly larger mean improvements, these differences were not statistically significant. This trend may be related to the neural and mechanical mechanisms described by some researchers, who reported that longer stretches could enhance muscle extensibility through increased stretch tolerance and altered neuromuscular activation patterns (Behm & Chaouachi, 2011; Donti et al., 2022; Takeuchi et al., 2023). Nevertheless, our results indicate that shorter sets can achieve

comparable outcomes when total stretching volume is controlled, which is particularly relevant in educational contexts where time efficiency is essential.

On the other hand, baseline differences in age and body mass index across groups were statistically controlled using ANCOVA. This adjustment minimized potential confounding effects, an essential methodological consideration given that age and body composition influence both muscle extensibility and responsiveness to stretching (Donti et al., 2022; Minato et al., 2020). Future research should further stratify participants to examine how developmental and anthropometric variables interact with flexibility adaptations.

The present findings hold important implications for Physical Education and school-based exercise programs. Adolescence represents a sensitive period for musculoskeletal development, as rapid growth can compromise hamstring flexibility, posture, and movement quality (Donti et al., 2022; Jozwiak et al., 1997; Konrad et al., 2024). By demonstrating that both short- and long-duration passive stretching protocols are effective, this study supports the inclusion of time-efficient flexibility routines that can be realistically implemented within standard class periods. Such interventions not only enhance flexibility but may also reduce injury risk, improve postural control, and support the acquisition of motor skills that foster lifelong physical activity participation.

Compared with previous studies, the current research adds methodological precision by equating total stretching volume and directly comparing two duration protocols under the same conditions. While previous investigations often differed in weekly frequency, total volume, or stretch intensity, the present design helps to isolate the role of the set duration. This approach strengthens the external validity of the findings for educational contexts, where time constraints and class organization are key factors in exercise prescription.

From a physiological perspective, passive stretching induces structural and neural adaptations, including increased sarcomere length, modifications in viscoelastic tissue properties, and enhanced stretch tolerance (Donti et al., 2022; Takeuchi et al., 2023). These mechanisms likely explain the significant gains observed in both intervention groups, regardless of stretch duration.

Interpretations of the results should also consider the measurement method. Although the Wells and Dillon test is widely validated and practical for school use (Castro-Piñero et al., 2009; López-Miñarro et al., 2009; Wells & Dillon, 1952), it assesses not only hamstring flexibility but also lumbar mobility. Therefore, future studies should include complementary assessments, such as the straight-leg raise or passive knee extension test, to isolate hamstring extensibility more precisely (Davis et al., 2008; Liu et al., 2022).

Finally, some limitations must be acknowledged. The quasi-experimental design and the impossibility of participant blinding may have introduced potential bias. Furthermore, the 10-week intervention period and session frequency may not capture the long-term adaptations achievable through prolonged school-based programs. Future studies should employ fully randomized controlled designs, larger samples, and follow-up assessments to evaluate the persistence of flexibility gains (Mayorga-Vega et al., 2014; Minato et al., 2020).

In conclusion, this study provides evidence that passive stretching effectively enhances hamstring flexibility in adolescents. When total stretching volume is kept constant, set duration does not substantially influence outcomes. These results support the implementation of time-efficient flexibility routines in school settings, offering a practical and evidence-based strategy to promote musculoskeletal health and functional mobility during adolescence.

Conclusions

After 10 weeks of intervention, both passive stretching programs, regardless of whether the sets lasted 60 seconds (EP-60) or 20 seconds (EP-20), produced significant improvements in hamstring flexibility among secondary school students. These results indicate that the total stretching volume, rather than the duration of individual sets, is the determining factor in flexibility gains, which supports the efficiency of shorter protocols when time constraints are present in educational contexts. Although the EP-60 group tended to achieve slightly greater improvements, no significant differences were observed between protocols, reinforcing the importance of accumulated stretching volume. Furthermore, both

stretching approaches improved sit-and-reach performance compared with the control group, suggesting their practical applicability for promoting musculoskeletal health, injury prevention, and postural balance in adolescents. Taken together, these findings highlight the relevance of implementing passive stretching programs in school-based Physical Education, providing educators with flexible and time-efficient strategies to enhance students' physical development and well-being.

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References

Alacid, F., & Soriano-Férriz, B. (2018). Flexibility programs and exercises within physical education classes, in schoolchildren, and their effect on the improvement of hamstring extensibility: a systematic review. *MHSalud*, 15(1), 1-13. https://doi.org/10.15359/mhs.15-1.1.

Araujo, C. G. S., de Souza e Silva, C. G., Kunutsor, S. K., Franklin, B. A., Laukkanen, J. A., Myers, J., Fiatarone Singh, M. A., França, J. F., & Castro, C. L. B. (2024). Reduced body flexibility is associated with poor survival in middle-aged men and women: A prospective cohort study. *Scandinavian Journal of Medicine & Science in Sports*, 34(8), 1157–1165. https://doi.org/10.1111/sms.14708.

Behm, D. G., Blazevich, A. J., Kay, A. D., & McHugh, M. (2016). Acute effects of muscle stretching on physical performance, range of motion, and injure incidence in healthy active individuals: A systematic review. *Applied, Physiology, Nutrition, and Metabolism*, 41(1), 1-11. https://doi.org/10.1139/apnm-2015-0235.

Behm, D. G., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. European *Journal of Applied Physiology*, 111, 2633–2651. https://doi.org/10.1007/s00421-011-1879-2.

Becerra-Fernández, C. A., Mayorga-Vega, D., & Merino-Marban, R. (2020). Effect of Physical Education-based stretching programs on hamstring extensibility in high school students: A systematic review. *Cultura, Ciencia y Deporte*, 15(43), 63–73. https://doi.org/10.12800/ccd.v15i43.1400.

Castro-Piñero, J., Chillón, P., Ortega, F. B., Montesinos, J. L., Sjöström, M., & Ruiz, J. R. (2009). Criterion-related validity of sit-and-reach and modified sit-and-reach tests for estimating hamstring flexibility in children and adolescents aged 6-17 years. *International Journal of Sport Medicine*, 30(9), 658–662. https://doi.org/10.1055/s-0029-1224175.

Da Costa, L., Ribeiro, I., Tebar, W., Oliveira, C., Guerra, P., Soidán, J. L., Mota, J., & Christofaro, D. (2022). Sedentary behavior is associated with musculoskeletal pain in adolescents: a cross-sectional study. *Brazilian Journal of Physical Therapy*, 26(5), 100452. https://doi.org/10.1016/j.bjpt.2022.100452.

Davis, D. S., Quinn, R. O., Whiteman, C. T., Williams, J. D., & Young, C. R. (2008). Concurrent validity of four clinical tests used to measure hamstring flexibility. *Journal of Strength and Conditioning Research,* 22(2), 583-588. https://doi.org/10.1519/jsc.0b013e31816359f2.

Donti, O., Konrad, A., Panidi, I., Dinas, P. C. & Bogdanis, G. C. (2022). Is There a "Windows of Opportunity" for Flexibility Development in Youth? A Systematic Review with Meta-Analysis. *Sport Medicine - Open,* 8(88). https://doi.org/10.1186/s40798-022-00476-1.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise,* 41(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278.

Jozwiak, M., Pietrzak, S., & Tobjasz, F. (1997). The epidemiology and clinical manifestations of hamstring muscle and plantar foot flexor shortening. *Developmental Medicine & child neurology*, 39(7), 481-483. https://doi.org/10.1111/j.1469-8749.1997.tb07468.x.

Kett, A. R., Milani, T. L., & Sichting, F. (2021). Sitting for Too Long, Moving Too Little: Regular Muscle Contractions Prevent Increased Stiffness during Prolonged Sitting. *Frontiers in Sports and Active Living*, 3, 760533. https://doi.org/10.3389/fspor.2021.760533.

Konrad, A., Alizadeh, S., Daneshjoo, A., Anvar, S. H., Graham, A., Zahiri, A., Goudini, R., Edwards, C., Scharf, C., & Behm, D. G. (2024). Chronic effects of stretching on range of motion with consideration of potential moderating variables: A systematic review with meta-analyses. *Journal of Sport and Health Science*, 13(2), 186-194. https://doi.org/10.1016/j.jshs.2023.06.002.

López-Miñarro, P. A., Muyor, J. M., & Alacid, F. (2012). Influence of hamstring extensibility on sagittal spinal curvatures and pelvic tilt in high-trained young kayakers. *European Journal of Sport Science,* 12(6), 469–474. https://doi.org/10.1080/17461391.2011.575476.

López-Miñarro, P. A., Sáinz de Baranda, P., & Rodríguez-García, P. (2009). A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university student. *Journal of Sport Science & Medicine,* 8(1), 116–122.

Liu, R., Li, F., Wang, T., Wang, S., & Zhou, C. (2012). Psychometric Properties of Four Common Clinical Test for Assessing Hamstring Flexibility in Young Adults. *Frontiers in Physiology,* 13, 911240. https://doi.org/10.3389/fphys.2022.911240.

Mayorga-Vega, D., Merino-Marban, R., & Viciana, J. (2014). Criterion-related validity of sit-and-reach tests for estimating hamstring and lumbar extensibility: A meta-analysis. *Journal of Sports Science & Medicine,* 13(1), 1–14.

Mayorga-Vega, D., Merino-Marban, R., & Viciana, J. (2015). A physical education-based stretching program performed once a week also improves hamstring extensibility in schoolchildren: a cluster-randomized controlled trial. *Nutrición Hospitalaria*, 32(4), 1715–1721. https://doi.org/10.3305/nh.2015.32.4.9302.

Merino-Marban, R., López-Fernández, I., & Mayorga-Vega, J. (2025). Physical Education-Based Stretching During Warm-Up, Cool-Down, or Both on Back-Saver Sit-and-Reach Scores in Schoolchildren. *Journal of Functional Morphology and Kinesiology,* 10(4), 151-158. https://doi.org/10.3390/jfmk10040383.

Merino-Marban, R., Mayorga-Vega, J., Fernández, E., Vera, F., & Viciana, J. (2015). Effect of a physical education-based stretching programme on sit-and-reach score and its posterior reduction in Schoolchildren. *European Physical Education Review,* 21(1), 83-92. https://doi.org/10.1177/1356336X14550942.

Minato, G., Ribeiro, R. R., Junior, A. A., & Santos, K. D. (2020). Idade, maturação sexual, variáveis antropométricas e composição corporal: influências na flexibilidade. *Revista Brasileira de Cineantropometria e Desempenho Humano,* 12(3), 383. https://doi.org/10.5007/1980-0037.2010v12n3p151.

Palanao, N., Nontakhod, K., Kusadet, N., Thongthuedee, A., & Intanoo, K. (2025). Effects of yoga exercise combined with passive stretching on the flexibility and strength of female students. *Retos: Nuevas tendencias en educación física, deporte y recreación,* 69, 1335-1343. https://doi.org/10.47197/retos.v69.116707.

Pérez Vigo, C., Myller, K., Sánchez, A., & Ayan, C. (2022). Improving hamstring flexibility through physical education-based interventions: a systematic review and meta-analysis. *Archivos de Medicina del Deporte,* 39(1), 50–61.

Rodríguez, P. L., Santonja, F. M.., López-Miñarro, P. A., Sáinz de Baranda, P., & Yuste, J. L. (2008). Effect of physical education stretching programme on sit-and-reach score in schoolchildren. *Science & Sports*, 23(3), 170–175. https://doi.org/10.1016/j.scispo.2007.12.013.

Takeuchi, K., Nakamura, M., Fukaya, T., Konrad, A., & Mizuno, T. (2023). Acute and long-term effects of static stretching on muscle-tendon unit stiffness: A systematic review and Meta-Analysis. *Journal of Sport Science and Medicine*, 22, 465-475. https://doi.org/10.52082/jssm.2023.465.

The Jamovi Project. (2025). *Jamovi (version 2.7.5)* [computer software]. https://www.jamovi.org

van Rensburg, L. J., & Coetzee, F. F. (2014). Effect of stretching techniques on hamstring flexibility in female adolescents. *African Journal for Physical, Health Education, Recreation and Dance,* 20(3), 1237–1248.

Wells, K. F., & Dillon, E. K. (1952). The sit and reach: A test of back and leg flexibility. *Research Quarterly. American Association for Health, Physical Education and Recreation*, 23(1), 115–118. https://doi.org/10.1080/10671188.1952.10761965.

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