Journal of Bodywork & Movement Therapies 38 (2024) 289–298

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Effect of Eutony, Holistic Gymnastics and Pilates on hamstring flexibility and back pain in pre-adolescent girls: Randomized clinical trial

Fernanda dos Santos Lopes Niaradi [a,*], Maíra Fonseca dos Santos Lopes Niaradi [a], Maria Elisabete Rodrigues Freire Gasparetto [b]

[a] Human and Rehabilitation Department: Graduate Program in Health, Interdisciplinarity and Rehabilitation from the Faculdade de Ciências Médicas da Universidade Estadual de Campinas, (UNICAMP), São Paulo, Brazil
[b] Medical Sciences from the State University of Campinas, Professor at The Department of Human Development and Rehabilitation of the Graduate Program in Interdisciplinary Health and Rehabilitation of the Faculdade de Ciências Médicas da Universidade Estadual de Campinas (UNICAMP), São Paulo, Brazil

ARTICLE INFO

Handling Editor: Dr Jerrilyn Cambron

Keywords:
Joint range of motion
Exercise therapy
Physical therapy modalities
Primary prevention

ABSTRACT

Objective: This study aimed to evaluate the effects of Eutony, Holistic Gymnastics, and Pilates on hamstring flexibility and back pain in pre-adolescent girls.
Methods: This randomized prospective quantitative clinical trial compared the effects of Eutony, Holistic Gymnastics, and Pilates on hamstring flexibility and back pain. The sample consisted of 80 pre-adolescent girls aged 10–13 years and divided into three groups: Eutony, with 26 girls; Holistic Gymnastics, 27 girls; and Pilates, 27 girls. The participants underwent ten 1-h weekly interventions. Hamstring flexibility was evaluated using fingertip-to-floor, sit-and-reach, and hip angle tests; back pain was evaluated using the Body Posture Evaluation Instrument questionnaire and the way they carried their backpack by the Layout for Assessing Dynamic Posture. Descriptive statistical analysis, analysis of variance, and Kruskal–Wallis test were performed at a 5 % significance level ($p < 0.05$).
Results: The three body practices increased hamstring flexibility in all fingertip-to-floor (7.77 cm), hip angle (5.58°), and sit-and-reach evaluations (9.07 cm). Before the intervention, 66.25 % of participants complained of back pain. After the intervention, only 37.50 % continued with the complaint. Moreover, 25 % of pre-adolescent girls started to carry their school backpack correctly.
Conclusion: Eutony, Holistic Gymnastics, and Pilates increased hamstring flexibility, reduced back pain complaints, and incentivized the girls to carry the school backpack correctly.
Registry of clinical trials: Brazilian Registry of Clinical Trials ReBEC (RBR-25w6kk).

1. Introduction

Flexibility is an important health-related physical fitness (Garber et al., 2011) that allows voluntary movements with maximum joint amplitude within physiological limits without pain or restrictions (Sands et al., 2016) and involves several structures, such as muscles, tendons, joint capsule, skin, and nerves (Le Sant et al., 2015).

Hamstring flexibility is important in performing basic human movements, such as sitting, walking, jumping, and running, and controlling posture (Kim and Shin, 2020). Reduced hamstring flexibility is common in adolescence, indicating health risk (Brodersen et al., 1994; Czaprowski et al., 2013; Liyanage et al., 2020).

Girls have greater flexibility than boys due to higher estrogen and collagen fiber concentrations, which increase joint and muscle amplitude (He et al., 2019; Lima et al., 2019; Golle et al., 2015). A study on 10-year-old children reported that 75 % of boys and 35 % of girls had low hamstring flexibility (Brodersen et al., 1994).

Sedentary lifestyle, physical inactivity, and sitting for a long time can influence lumbopelvic kinematics and reduce hamstring flexibility (Zawadka et al., 2022; Fatima et al., 2017). Moreover, girls are more sedentary than boys (Condessa et al., 2019; Cureau et al., 2016; Salvo et al., 2020; Guthold et al., 2020). A study on adolescents reported that 78 % of boys and 89.4 % of girls aged 11–17 years do not reach the recommended minimum physical activity level (Guthold et al., 2020).

Reduced hamstring flexibility can trigger acute and chronic pathologies and injuries, such as low back pain (van Middelkoop et al., 2011;

* Corresponding author. Dr. Pelágio Lobo, 142 sala 02 Jardim Brasil, Campinas, Cep 13073-013, Brazil.
E-mail address: fer.fisio2012@gmail.com (F.S.L. Niaradi).

https://doi.org/10.1016/j.jbmt.2024.01.017
Received 9 August 2022; Received in revised form 15 November 2023; Accepted 13 January 2024
Available online 28 January 2024

Jozwiak et al., 1997; Feldman et al., 2001), lumbar disk herniation (Takata and Takahashi, 1994; Zhu et al., 2006), lumbar lordosis reduction (Jozwiak et al., 1997), reduced thoracic spine range of motion in flexion (Gajdosik et al., 1994), and increased angle of thoracic kyphosis in adolescents with Scheuermann's disease (Fisk et al., 1984).

Physical activity can improve reduced hamstring flexibility, with evidence supporting the use of exercise as a therapeutic tool to increase hamstring flexibility. Hamstring flexibility can be improved using different physical activity approaches, such as Pilates (González-Gálvez et al., 2015, 2019, 2020, 2020, 2020; González-Gálvez et al., 2020a,b,c; González-Gálvez et al., 2020a,b,c), Yoga (Donahoe-Filmore and Grant, 2019), Holistic Gymnastics (Niaradi and Batista, 2018), sports (Schubert et al., 2016), and stretching (Czaprowski et al., 2013). Adequate muscle flexibility in adolescence prevents low back pain and reduces the incidence of neck pain in adulthood (Mikkelsson et al., 2006).

Back pain is a musculoskeletal disorder (Kedra et al., 2019) that often causes disability (Dullien et al., 2018; Beynon et al., 2019) and increases financial costs for the individual and society (Kedra et al., 2019), representing a public health problem (Bazett-Jones et al., 2019; Noll et al., 2016a,b; Noll et al., 2021).

Some studies showed that back pain is highly prevalent in children and adolescents (Kedra et al., 2019; Beynon et al., 2019; Bazett-Jones et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b) and that pain complaints are not always transient. Approximately 50 % of young people report having the same pain years later (Bazett-Jones et al., 2019; Noll et al., 2021), increasing the risk of lesions in adulthood (Kedra et al., 2019; Dullien et al., 2018). In Brazil, a longitudinal study with adolescents indicated an initial prevalence of back pain of 55.7 %, which increased to 65.9 % after a 3-year follow-up (Noll et al., 2021), with possible consequences such as increased number of medical appointments, school absenteeism, and limited daily living and physical activities that affect social behavior, causing appetite, sleep, and mental health disorders, increasing anxiety and depression, and affecting quality of life (Bazett-Jones et al., 2019; Blanco-Morales et al., 2020).

The main risk factors for back pain are female sex (Noll et al., 2021; Fabricant et al., 2020; Kedra et al., 2019; Beynon et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b), older age (Noll et al., 2021; Dullien et al., 2018; Beynon et al., 2019; Noll et al., 2016a,b), growth spurt (Noll et al., 2021; Beynon et al., 2019), heredity (Noll et al., 2016, 2021; Beynon et al., 2019), sedentary lifestyle (Noll et al., 2021; Beynon et al., 2019; Kedra et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b), heavy backpack (Beynon et al., 2019; Kedra et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b), carrying a backpack incorrectly (Noll et al., 2021; Beynon et al., 2019; Kedra et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b), school furniture incompatible with the student's size (Assiri et al., 2019), inappropriate posture in daily living activities (Noll et al., 2016a,b), long periods of physical activity (Beynon et al., 2019; Dullien et al., 2018), anxiety disorders (Beynon et al., 2019; Bazett-Jones et al., 2019; Noll et al., 2016a,b), depression (Kedra et al., 2019; Beynon et al., 2019), and sleep disturbance (Kedra et al., 2019; Beynon et al., 2019; Bazett-Jones et al., 2019; Noll et al., 2016a,b). It is important to note that the use of backpacks can cause pain in the shoulders. One study showed that 30.8 % of students carried backpacks with more than 10 % of body weight and about 88.2 % of students reported pain in the neck, shoulders, and upper back (Mwaka et al., 2014) Another recent study found that shoulder pain was much more frequent than back pain. (Hernández et al., 2020).

Assuming a reduction in physical activity levels in the transition from childhood to adolescence, with a higher prevalence in girls (Condessa et al., 2019; Cureau et al., 2016; Salvo et al., 2020; Guthold et al., 2020), there is also a reduction in hamstring flexibility (Brodersen et al., 1994; Czaprowski et al., 2013; Liyanage et al., 2020), with girls presenting higher back pain frequency (Noll et al., 2021; Fabricant et al., 2020; Kedra et al., 2019; Beynon et al., 2019; Dullien et al., 2018; Noll et al., 2016a,b) and intensity (Noll et al., 2021) than boys. Therefore, physical activity programs in the school environment to prevent and rehabilitate hamstring flexibility and back pain at this stage of life are extremely important to avoid medicalization and chronicity in adulthood (Mikkelsson et al., 2006; Beynon et al., 2019; Bazett-Jones et al., 2019; Noll et al., 2021).

Some studies showed that Holistic Gymnastics (Niaradi and Batista, 2018) and Pilates (González-Gálvez et al., 2015, 2019, 2020, 2020, 2020; González-Gálvez et al., 2020a,b,c; González-Gálvez et al., 2020) increase hamstring flexibility; however, no studies in the literature showed the relationship between Eutony and increased hamstring flexibility in adolescents. Furthermore, there is a gap in the literature for studies on intervention programs aimed at reducing back pain in pre-adolescents.

Of the physical activity proposals, this study highlights Eutony, Holistic Gymnastics, and Pilates, which play an important role in increasing hamstring flexibility (Niaradi and Batista, 2018; González-Gálvez et al., 2015, 2019, 2020, 2020, 2020; González-Gálvez et al., 2020a,b,c; González-Gálvez et al., 2020a,b,c) and reducing back pain complaints in pre-adolescents. Eutony and Holistic Gymnastics belonged to the field of Somatic Education, which has an integral view of the human being and stimulates sensorimotor, cognitive, and affective aspects to develop body awareness (Niaradi et al., 2022). Each Eutony and Holistic Gymnastics class includes activities aimed at relaxation, postural reeducation, respiratory function balance, body awareness development, and stretching movements (Niaradi and Batista, 2018; Niaradi et al., 2022). The Pilates method includes low-impact movements at a slow pace and with few repetitions. The objective of this method is to promote muscle stretching and strengthening (González-Gálvez et al., 2015, 2019, 2020, 2020, 2020; González-Gálvez et al., 2020a,b,c; González-Gálvez et al., 2020a,b,c).

Thus, the present study aimed to analyze the effects of Eutony, Holistic Gymnastics, and Pilates on hamstring flexibility and back pain to define whether the ergonomic guidelines were understood and encourage the practice of physical activity in pre-adolescent girls.

2. Methods

2.1. Study characteristics

This is a three-arm randomized controlled clinical trial with parallel design. Due to the type of intervention, neither the pre-adolescents nor the therapists could be blinded, making this an open-ended study.

A prospective and randomized quantitative clinical trial was conducted and approved by the research ethics committee of the State University of Campinas, SP, Brazil, under approval no. 1869.831/CAEE 61623316.1.0000.5404, and registered in the Brazilian Registry of Clinical Trials (ReBEC) (RBR-25s6kk). The participants' parents and guardians signed the Informed Consent Form (ICF), and the participants signed the Informed Assent Form (IAF) before initiation of the study.

2.2. Participants

The estimated sample size was 90 participants divided into three groups of 30 pre-adolescents in each body practice. In schools there were 481 pre-adolescents enrolled in the fifth, sixth and seventh grades of elementary school. However, 378 were excluded for various reasons such as age, schedule of practical activities, parents or guardians not authorizing participation and lack of interest of participants. The study included 103 pre-adolescent girls aged 10–13 years enrolled in elementary school who were evaluated and randomized into three intervention groups based on the body movement practice used: Eutony, Holistic Gymnastics, and Pilates. The inclusion criteria were female sex with age of 10–13 years with no health problems and an ICF signed by parents or guardians. The exclusion criteria were pre-adolescents in special education and disabilities; orthopedic, rheumatic, or neurological disease sequelae; use of limb prostheses; pain during physical activities; and impediments to the use of swimming suits. However, no

clinical evaluation and laboratory tests were performed to diagnose neurological or rheumatic diseases. Eighteen pre-adolescents were excluded from the study for not meeting age-related inclusion criteria. The final sample consisted of 80 pre-adolescents divided into the Eutony (n = 26), Holistic Gymnastics (n = 27), and Pilates (n = 27) groups, as shown in Fig. 1. The study protocol followed the Consolidated Standards of Reporting Trials (CONSORT) 2010 statement (Niaradi et al., 2022) (Fig. 1).

2.3. Study site

The study was conducted in six public schools (three municipal and three state schools) in Campinas, SP, Brazil. In four schools, a lecture was given to parents and/or guardians to explain the research project in detail. In three schools, parents had little adherence, and in the fourth school, the principal included the lecture at a school meeting attended by approximately 60 parents. In the other two schools, the head researcher visited the classrooms during normal class hours and presented the project to the pre-adolescents, who took the ICF home to be signed. The data were collected in the rooms intended for project activities. Flexibility and back pain evaluations and practical classes were conducted in classrooms adapted for the activities (desks were removed), computer and teacher rooms, libraries, video rooms, material rooms, and external school areas.

2.4. Evaluation and randomization

Flexibility and back pain were evaluated by the head researcher in all pre-adolescents before enrolling them as study participants. The evaluations were scheduled by telephone, with two girls per hour. While one answered the back pain questionnaire, the other underwent anthropometric and flexibility evaluation. The schools provided a room with adequate lighting and privacy as the pre-adolescents wore bathing suits for the flexibility assessment and weight and height measurements.

Flexibility was evaluated using three measurement strategies: photogrammetry to analyze the lumbar and pelvic joint angles, fingertip-to-floor test, and sit-and-reach test.

Photogrammetry and fingertip-to-floor test were performed with the participant in the same left profile position, standing with feet together, knees extended, and trunk leaning forward. Then, the participant was asked to try to reach the floor with the fingertips, keeping the knees stretched and the upper limbs and head relaxed.

In photogrammetry, the pre-adolescents were photographed after locating and demarcating the anatomical points proposed by the Postural Analysis Software 2016 (PAS/SAPO). These anatomical points were marked with small Styrofoam balls (1 cm diameter) wrapped with double-sided adhesive tape and placed in the specific points suggested by the PAS. The photograph was taken with a Nikon Coolpix S2900 digital camera on a 0.85-cm-high tripod. The images were analyzed by measuring the angle between the femoral trochanter, acromion, and posterosuperior iliac spine using the PAS, which is a reliable and

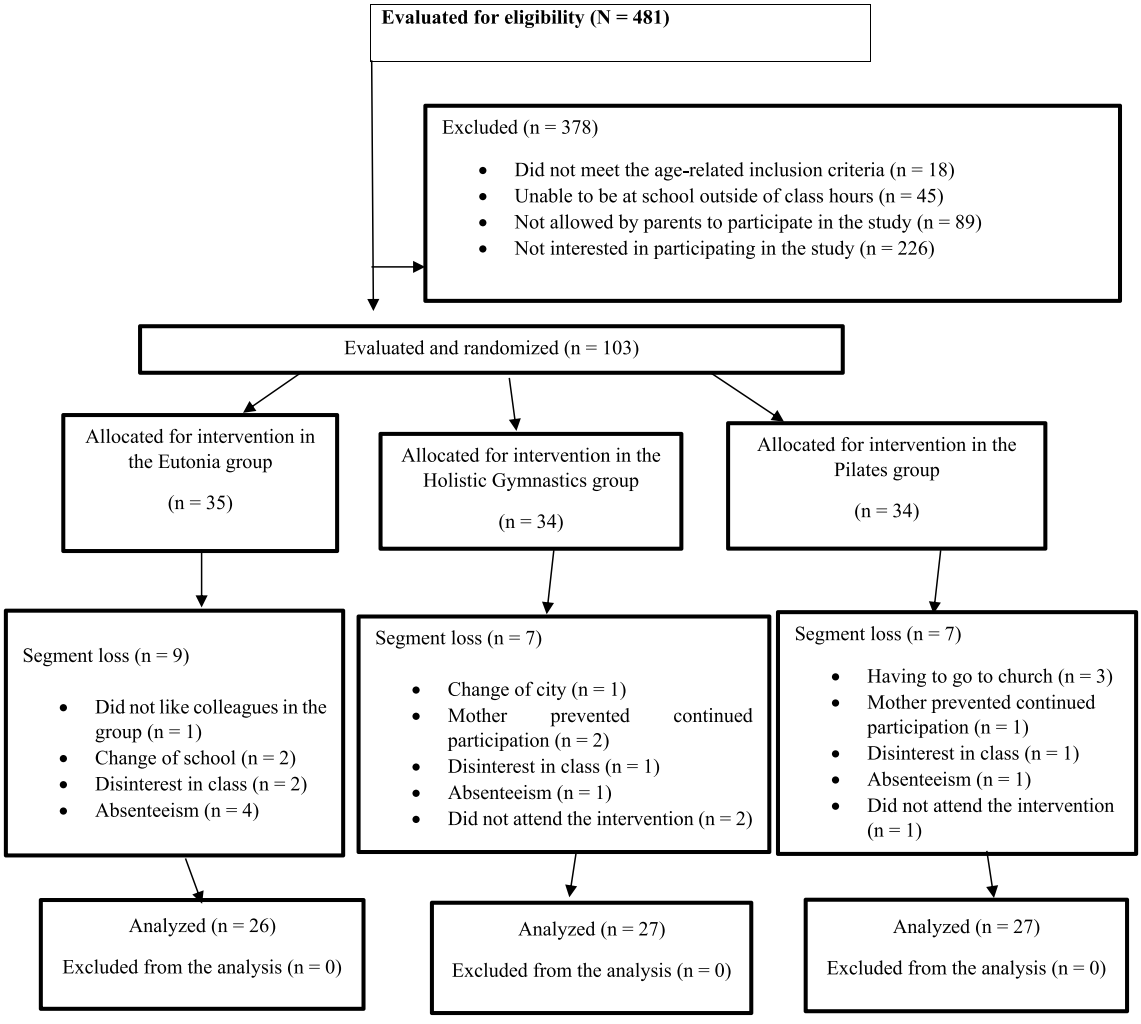

Fig. 1. Study flow diagram.

accurate instrument for measuring body angles and distances (Ferreira et al., 2010; Guariglia et al., 2011).

In the fingertip-to-floor evaluation, a tape measure was used to measure the distance from the third finger of the left hand to the floor. The reliability of measurements in this test was >0.9. For Bland and Altman (1997), this result determines excellent reliability. The measurement error level seems to be low; therefore, we understand that it did not influence the interpretation of the results.

In the sit-and-reach test, a 1.50 measuring tape was fixed on the floor, and a 30-cm tape was perpendicularly fixed on top of this tape at the mark of 38 cm, with 15 cm extending to the right and left sides.

The participants were tested bare feet, in a sitting position with legs apart and extended, by placing their right foot on the right end of the tape and their left foot on the left end. With the spine straight and arms stretched toward the ceiling, the middle finger of the right hand was placed on the left hand, and inhaling and stretching the spine, they flexed the trunk to achieve maximum stretching. This movement was repeated three times, and the greatest measurement was considered. The sit-and-reach test has a moderate mean validity for measuring hamstring flexibility (0.46–0.67) (Mayorga-Vega et al., 2014).

Back pain was evaluated using the version for women of the Body Posture Evaluation Instrument (BackPEI) (Noll et al., 2012), which is a self-administered, valid, and reproducible questionnaire containing 21 closed questions about demographic, socioeconomic, and behavioral issues; heredity; and occurrence of back pain.

The way the participants carried the school backpack was evaluated by the Layout for Assessing Dynamic Posture (LADy) (Noll et al., 2016a, b), a validated instrument that verifies daily postures through filming. In this study, only the photographs of the pre-adolescents carrying the school backpack before and after the intervention were taken, which were analyzed by the head researcher. The instrument uses a final numerical scoring criterion, and the higher the score, the more correctly the activity of daily living was performed.

Anthropometric evaluation included the participant's body mass and height and weight of their backpacks. Body mass was measured using a digital anthropometric scale graduated from 0–150 kg and resolution of 0.05 kg, being registered in kilograms with a decimal point. Height was measured in centimeters using a measuring tape extended and fixed to the wall, with the participants in an upright position, leaning their heels and trunk against the wall and keeping their eyes horizontally. The body mass index was analyzed by the PAS. Evaluation and BackPEI registration lasted about 60 min. Parents answered a 15-item questionnaire to collect information about personal and social aspects of the participants.

After the initial flexibility and back pain evaluation, the pre-adolescents were randomly assigned into one of three intervention groups using a simple randomization process: Eutony, Holistic Gymnastics, and Pilates groups.

The randomization process was done through a draw made by the secretary of each school. All participants were placed in a paper bag and the secretary drew and distributed among the three body practices (Eutony, Holistic Gymnastics and Pilates). Evaluations and interventions were conducted before or after school hours.

Thus, three groups of three to nine participants were formed in each group for the practical activities of Eutony, Holistic Gymnastics, and Pilates. Each group attended a weekly 1-h class for ten weeks, with a total of 10 h of intervention in each modality. After 10 h of intervention, flexibility and back pain were re-evaluated in 80 pre-adolescents using a method similar to the one used in the initial assessment. Participants who missed interventions were offered a replacement class with the same specific content at another time, and a maximum of three absences were allowed. Participants who exceeded this limit were automatically excluded from the project.

2.5. Intervention

The dynamics of all classes has already been described in detail in the study by Niaradi et al. (2022). Figs. 2–4 show images of the students in the Eutony, Holistic Gymnastics, and Pilates classes. The duration of the research was about 4 months in each school.

2.6. Statistical analysis

Sample profile was described by descriptive statistics with mean and standard deviation. The repeated measures analysis of variance (ANOVA), known as a nonparametric analysis model for longitudinal profiles, was used to compare numerical results between groups and times. This test was selected due to the non-normal distribution of the data, which requires more robust nonparametric techniques that do not assume data distribution. The Kruskal-Wallis test and ANOVA were used to evaluate flexibility and how they carried the school backpack, including back pain, at a 5 % significance level ($p < 0.05$).

3. Results

Table 1 shows the characterization of the pre-adolescents in the pre-intervention moment (Niaradi et al., 2022). Fig. 5 shows behavioral aspects, with 66.25 % of the participants not practicing physical activities or sports outside school, 64.47 % practicing sedentary leisure activities, 65.00 % having a cell phone, 68.75 % not menstruating, and 73.75 % carrying up to 10 % of their body weight in their school backpack (Niaradi et al., 2022) (Fig. 5).

Table 2 shows the results related to the three hamstring flexibility measurements and the way of carrying the school backpack in the three groups (Eutony, Holistic Gymnastics, and Pilates). The fingertip-to-floor test, lumbar and pelvic joint angle, sit-and-reach test, and way of carrying the backpack showed that the periods are statistically significant for the three body practices. The comparison between pre- and post-

Fig. 2. Eutony class.

Fig. 3. Holistic Gimnastic class.

Fig. 4. Pilates class.

intervention measurements indicated increased hamstring flexibility, and some pre-adolescents started to carry the backpack correctly in the three body practice groups.

Table 1
Characterization of physical parameters of the pre-adolescents.

Pre-intervention	Eutonia n = 26	Ginástica Holística n = 27	Pilates n = 27
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	11.15 ± 1.08[a]	10.96 ± 1.02[a]	10.89 ± 0.93[a]
Body mass (kg)	45.21 ± 13.22[a]	43.96 ± 13.59[a]	44.65 ± 14.55[a]
Height (cm)	1.52 ± 0.10[a]	1.51 ± 0.11[a]	1.49 ± 0.10[a]
BMI (kg/cm$^{2)}$	19.31 ± 4.75[a]	19.01 ± 4.04[a]	19.88 ± 4.82[a]

SD: standard deviation; n: number of pre-adolescents.
*Average followed by the same lowercase letters do not show significant difference among the groups at $p < 0.05$. (Niaradi et al., 2022). Source: the authors.

Table 3 shows the ANOVA for physical activity practices and their post-intervention effect on hamstring flexibility and backpack carrying. As for hamstring flexibility, the results showed no significant difference between physical activity practices ($p < 0.05$). However, regardless of the adopted intervention, hamstring flexibility increased with the three forms of evaluation: fingertip-to-floor test ($p < 0.001$), lumbar and pelvic joint angle ($p < 0.001$), and sit-and-reach test ($p < 0.001$). As for backpack carrying, 99 % of participants had a score between 2 and 3 points before the intervention, with 85 % of them increasing to 3 points after. As for back pain, 53 pre-adolescents reported back pain before the intervention, and after the intervention, only 30 complained of it.

Table 4 presents the results regarding back pain and backpack carrying. Back pain complaints were reduced in pre-adolescent girls after the intervention. At the pre-intervention moment, 66.25 % of the pre-adolescents complained of back pain and, at the post-intervention moment, only 37.5 % reported back pain, suggesting that Eutony, Holistic Gymnastics, and Pilates practices reduced back pain in the participants. As for the way of carrying their backpacks, 52.5 % of pre-adolescents carried the backpack correctly at the pre-intervention moment, with an increase to 80 % after the intervention.

Fig. 6 shows the results of all hamstring flexibility, backpack carrying, and back pain variables (Fig. 6).

4. Discussion

The main results of this study indicated that the participants who practiced Eutony, Holistic Gymnastics, and Pilates showed increased hamstring flexibility and reduced back pain and learned the correct way of carrying their school backpack.

Hamstring flexibility was analyzed using three different forms of evaluation (fingertip-to-floor test, sit-and-reach test, and hip angle measurement). Hamstring flexibility measured using the fingertip-to-floor test increased by 10.47, 7.22, and 5.64 cm after ten intervention sessions with Eutony, Holistic Gymnastics, and Pilates, respectively. Niaradi and Batista (2018) showed that nine sessions of Holistic Gymnastics increased the flexibility of girls aged 10–12 years by 7.7 cm. González-Gálvez et al. (2015) reported that 12 sessions of Pilates increased the hamstring flexibility of adolescent girls with a mean age of 14 years by 3.85 cm. González-Gálvez et al. (2020a,b,c) evaluated the effect of 10-min Pilates session in Physical Education classes in adolescents of both sexes aged 14 years during a 12-week period and reported a hamstring flexibility increase of 2.75 cm. González-Gálvez et al. (2020a,b,c) analyzed the effectiveness of a Pilates exercise program over a nine-month period in adolescents of both sexes and reported a hamstring extensibility increase of 2.04 cm. Czaprowski et al. (2013) showed that a six-week exercise program comparing three types of intervention with post-isometric relaxation, static stretching combined with stabilizing exercises, and stabilizing exercises in adolescents of both sexes aged 10–13 years promoted a hamstring flexibility increase of 2.54 cm.

Hamstring flexibility also increased of 9.89, 9.03, and 8.29 cm in the present study in the sit-and-reach test after the Eutony, Holistic Gymnastics, and Pilates interventions, respectively. Donahoe-Filmore and

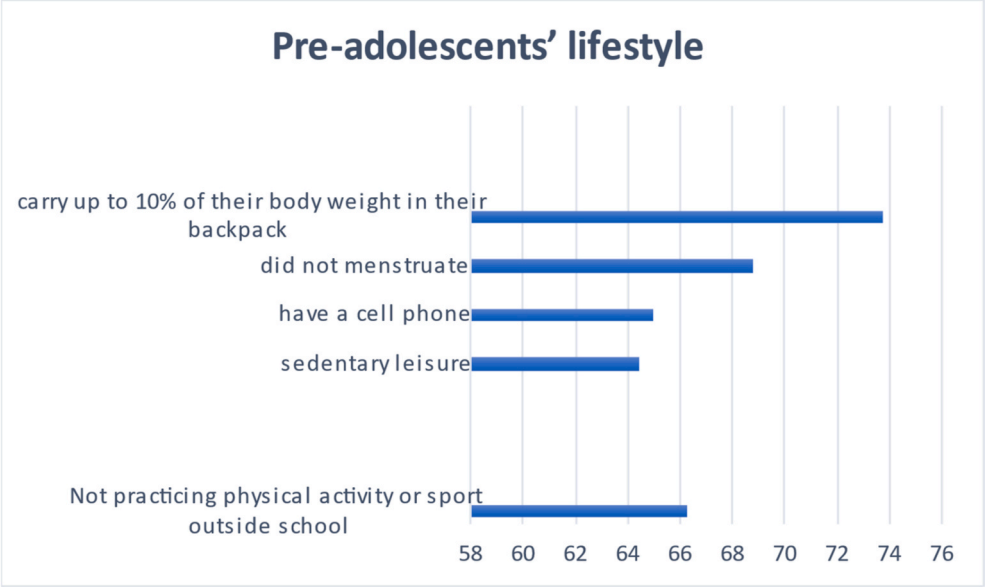

Fig. 5. Pre-adolescents' lifestyle.

Table 2
Mean on hamstring flexibility and schoolbag, before and after intervention of Eutonia, Holistic Gymnastics and Pilates.

Variables	Body Practices	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	p-value grupo	p-value tempo	p-value tempo*grupo
Fingertip-to floor (FTF) (cm)	Eutonia (n = 26)	15.12 ± 11.71	4.65 ± 9.86	0.9453*	**<0.001****	0.1705***
	Holistic Gymnastics (n = 27)	12.81 ± 7.70	5.59 ± 5.96			
	Pilates (n = 27)	12.57 ± 8.93	6.93 ± 7.46			
Hip joint angle HJA (°)	Eutonia (n = 26)	80.44 ± 11.17	87.95 ± 7,99	0.4879*	**<0.001****	0.2514***
	Holistic Gymnastics (n = 27)	82.71 ± 7.14	88.51 ± 5.13			
	Pilates (n = 27)	85.50 ± 7.75	88.94 ± 5.69			
Sit-and- reach test (SRT) (cm)	Eutonia (n = 26)	21.97 ± 3.00	31.86 ± 11.66	0.3686*	**<0.001****	0.9742***
	Holistic Gymnastics (n = 27)	26.37 ± 9.66	35.40 ± 20.00			
	Pilates (n = 27)	25.36 ± 7.66	33.65 ± 14.33			
Schoolbag (3 points)	Eutonia (n = 26)	1.88 ± 0.65	2.08 ± 0.63	0.8265*	**<0.0005****	0.3434***
	Holistic Gymnastics (n = 27)	1.93 ± 0.62	2.22 ± 0.80			
	Pilates (n = 27)	1.81 ± 0.74	2.30 ± 0.82			

SD: standard deviation; n: number of participants. Statistically significant at $p < 0,05$. Statistically significant difference in bold.
Teste Kruskal-wallis.
Source: the authors.

Grant (2019) suggested that the practice of Yoga for eight weeks promoted a hamstring flexibility increase of 5.54 cm in children of both sexes aged 10–12 years. Schubert et al. (2016) concluded that the practice of individual sports by children and adolescents aged 8–16 years increased hamstring flexibility by 2.32 cm.

As for hip angle, flexibility increased at 7.51°, 5.80°, and 3.44° in this study after the Eutony, Holistic Gymnastics, and Pilates intervention, respectively. Niaradi and Batista (2018) concluded that a nine-week Holistic Gymnastics program increased hamstring flexibility by 5.6° in girls aged 10–12 years.

Thus, there is a consensus in the literature that physical activities and sports increase hamstring flexibility. Eutony, Holistic Gymnastics, and Pilates showed higher hamstring flexibility increases in the three evaluations than in the presented studies (González-Gálvez et al., 2015, 2020, 2020; González-Gálvez et al., 2020a,b,c; Czaprowski et al., 2013; Donahoe-Filmore and Grant, 2019; Schubert et al., 2016). However, the study by Niaradi and Batista (2018) showed a slight hamstring flexibility improvement with the fingertip-to-floor test, and one of the hypotheses for this result is the fact that the participants were younger.

The results of the present study also showed clear hamstring flexibility differences between body practices in the three evaluation measurements. The pre-adolescents in the Eutony group had better hamstring flexibility results than the ones in the Holistic Gymnastics and Pilates groups. Furthermore, the pre-adolescents in the Eutony group had more shortened hamstring muscles before the intervention than the ones in the Holistic Gymnastics and Pilates groups. It is not possible to directly explain this difference, and one of the hypotheses for these results is that Eutony is a Somatic Education method that includes sensory, proprioceptive, and relaxation stimuli; however, Holistic Gymnastics is also a Somatic Education method that contains the same elements (Niaradi et al., 2022). Further experimental clinical studies should be developed with different Somatic Education methods to better understand the influence of different methods on hamstring flexibility.

Flexibility decreases between 10 and 13 years of age because bone growth exceeds muscle stretching, which is important for motor development as stretching movements increase the number of sarcomeres and muscle stretching, resulting in joint balance, postural alignment, and increased flexibility (Sands et al., 2016). In this study, stretching was present in all Eutony, Holistic Gymnastics, and Pilates classes and contributed to increased flexibility. Since stretching is present in Eutony, Holistic Gymnastics (Niaradi and Batista, 2018), Pilates (González-Gálvez et al., 2015, 2019, 2020, 2020; González-Gálvez et al.,

Table 3
Analysis of variance (ANOVA) of hamstring flexibility, school bag and back pain between the body practices and pre-and post-intervention.

Variables	Statistic	p-value
Fingertip-to floor (FTF)		
Body Practices	0.06	0.94
Time (pre- and post-intervention)	102.73	<0.001*
Interaction: Body Practices & Time	1.81	0.17
Hip joint angle (HJA)		
Body Practices	0.71	0.48
Time (pre- and post-intervention)	69.75	<0.001*
Interaction: Body Practices & Time	1.40	0.25
Sit-and-reach test (SRT)		
Body Practices	1.02	0.36
Time (pre- and post-intervention)	120.71	<0.001*
Interaction: Body Practices & Time	0.03	0.97
How to carry the school bag		
Body Practices	2.40	0.09
Time (pre- and post-intervention)	26.82	<0.001*
Interaction: Body Practices & Time	0.42	0.65
Back pain		
Body Practices	0.29	0.75
Time (pre- and post-intervention)	34.16	0.00*
Interaction: Body Practices & Time	0.26	0.77

*Significant at $p < 0,05$. Source: the authors.

2020a,b,c), Yoga (Donahoe-Filmore and Grant, 2019), sports (Schubert et al., 2016), and gymnastics (Sands et al., 2016), it is possible to affirm that this is an essential element for increasing flexibility. Nevertheless, the optimal parameters for stretching exercises have not been established, so it is difficult to compare results with other studies due to different age ranges, types of stretching, number of repetitions, and exercise sets or duration.

The present study showed that Brazilian pre-adolescents present greater hamstring shortening than pre-adolescents from other countries. In this study, hamstring flexibility by the fingertip-to-floor test showed a mean of 13.50 cm before the intervention, and the study by Niaradi and Batista (2018) showed a mean of 16.8 cm. Czaprowski et al. (2013) conducted a study in Poland with pre-adolescents of the same age group and reported a mean of 6.27 cm. González-Gálvez et al. (2015, 2020) conducted studies in Spain and determined means of 2.81 and 9.87 cm, respectively. In the present study, the sit-and-reach test presented a mean of 24.56 cm, and the study by Schubert et al. (2016), which was also conducted in Brazil, showed a mean of 28.92 cm for girls. The study by Donahoe-Filmore and Grant (2019), which was developed in the United States, showed a means of 8.23 cm.

One explanation for these results is the sedentary lifestyle of Brazilian pre-adolescents, with 66.25 % not practicing physical activities, body practices, or sports outside school, and 61.25 % reporting sedentary leisure activities, such as watching TV and going to church, which corroborates the literature (Condessa et al., 2019; Cureau et al., 2016; Salvo et al., 2020; Guthold et al., 2020; Noll et al., 2021). The results suggest the need to expand the assessment of hamstring flexibility in schools to identify this problem and propose changes to increase the scope of its health benefits for this population.

Back pain significantly reduced in the pre-adolescents after the intervention, suggesting an improvement of 28.75 % in the participants. Blanco-Morales et al. (2020) conducted a qualitative study on adolescents with back pain who were aged 15–17 years, in which a workshop on ergonomics, stretching, and massage was performed during the period of 27 months and reported that all adolescents noted decreased

Table 4
Frequency of back pain and backpack variables between body practices before and after the intervention.

Variables	Body practices	Pre-intervention N %	Post-intervention N %	Total Pre-intervention	Total Post-intervention
Back pain					
	Eutony (n = 26)	16 (61.53)	9 (34.61)		
	Holistic Gymnastics (n = 27)	20 (74.07)	11 (40.74)	53	30
	Pilates (n = 27)	17 (62.96)	10 (37.03)		
Pain frequency					
	Eutony (n = 26)	7 (26.92)	7 (26.92)		
Pain only once	Holistic Gymnastics (n = 27)	9 (33.33)	4 (14.81)	27	15
	Pilates (n = 27)	11 (40.74)	4 (14.81)		
	Eutony (n = 26)	6 (23.07)	0 (0.00)		
Pain once a month	Holistic Gymnastics (n = 27)	3 (11.11)	2 (7.40)	9	3
	Pilates (n = 27)	0 (0.00)	1 (3.70)		
Pain intensity					
	Eutony (n = 26)	7 (26.92)	7 (26.92)		
(1–3)	Holistic Gymnastics (n = 27)	10 (37.03)	6 (22.22)	28	19
	Pilates (n = 27)	11 (40.74)	6 (22.22)		
	Eutony (n = 26)	8 (30.76)	2 (7.69)		
(4–5)	Holistic Gymnastics (n = 27)	6 (22.22)	2 (7.40)	19	6
	Pilates (n = 27)	5 (18.51)	2 (7.40)		
Back pain heredity					
	Eutony (n = 26)	9 (34.61)	8 (30.76)		
Mother	Holistic Gymnastics (n = 27)	9 (33.33)	10 (37.03)	29	30
	Pilates (n = 27)	11 (40.74)	12 (44.44)		
	Eutony (n = 26)	6 (23.07)	5 (19.23)		
Father	Holistic Gymnastics (n = 27)	7 (25.92)	5 (18.51)	20	17
	Pilates (n = 27)	7 (25.92)	7 (25.92)		
Way of carrying the backpack					
	Eutony (n = 26)	14 (53.84)	19 (73.07)		
Symmetrical shoulder straps	Holistic Gymnastics (n = 27)	16 (59.25)	21 (77.77)	49	69
	Pilates (n = 27)	19 (70.37)	24 (88.88)		

N (number of pre-adolescents); % (percentage).
Source: the authors

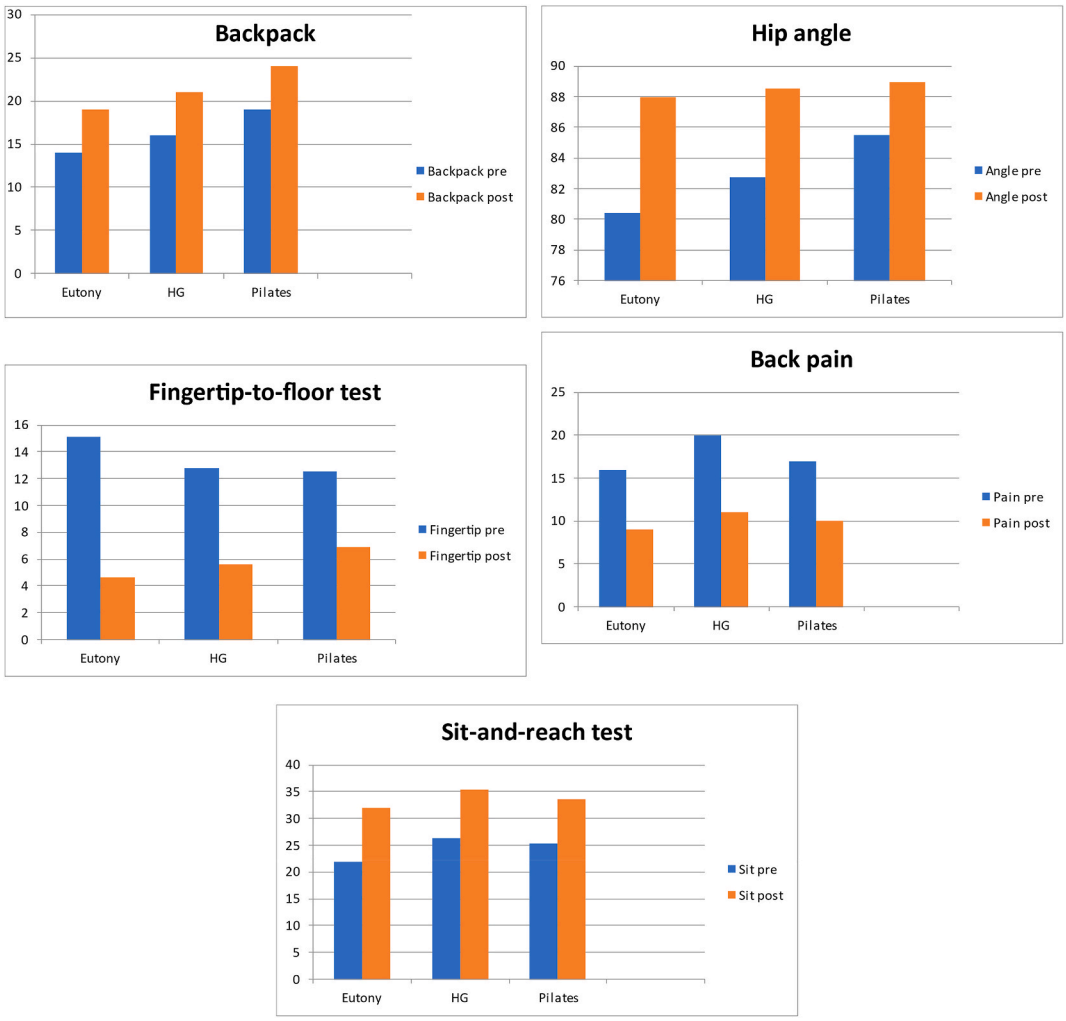

Fig. 6. The results of all hamstring flexibility, backpack carrying, and back pain.

back pain and assimilated the guidelines. González-Gálvez et al. (2019) associated back pain with lack of trunk resistance and flexibility and analyzed the effectiveness of Pilates sessions twice a week for six weeks in adolescents of both sexes with back pain who were aged 14–16 years and divided into the Pilates and control groups. The results suggested that participants in the Pilates group increased trunk strength and flexibility.

Dissing et al. (2018) investigated the effectiveness of manual therapy associated with guidance, stretching and strengthening exercises, and massage on back pain in schoolchildren aged 9–15 years and reported that manual therapy did not reduce back pain in the participants. Dullien et al. (2018) analyzed an education, behavior, and exercise program to reduce back pain in schoolchildren aged 10–12 years and reported no back pain decrease.

Some studies show that both relaxation and stretching have positive effects in reducing back pain in children and adolescents (Blanco-Morales et al., 2020; González-Gálvez et al., 2019; Dissing et al., 2018). In the present study, relaxation was present in all Eutony and Holistic Gymnastics classes through self-massage and proprioceptive stimuli with different materials. Blanco-Morales et al. (2020) and Dissing et al. (2018) also used massage for relaxation and reported reduced back pain. Stretching was present in all body practice classes in this study. González-Gálvez et al. (2019), Blanco-Morales et al. (2020), and Dissing et al. (2018) also used this element and obtained good results in reducing back pain. Thus, we can suggest that relaxation and stretching are important elements in reducing back pain even when used in different ways and with specific characteristics.

This study reported a back pain prevalence of 66.25 % in pre-adolescents. Noll et al. (2021) showed that the prevalence of back pain increased by 10.00 % in a three-year period, from 56.00 % to 65.90 %. Kedra et al. (2019) reported a prevalence of 74.40 %, and Fabricant et al. (2020) reported a prevalence of 33.70 %. The main risk factors for these results were sedentary lifestyle and backpack weight and way of carrying.

In the present study, the pre-adolescents had a sedentary lifestyle. Similar results were found by Noll et al. (2021), who reported that participants spent more than 6 h watching TV. Physical inactivity with long periods in an inadequate sitting position can generate pressure on the intervertebral discs, accelerating musculoskeletal degeneration and lumbopelvic imbalance associated with general discomfort, fatigue, and pain (Noll et al., 2016, 2021). Girls are less active, and the hypotheses include having less muscle mass, having less aerobic fitness, not enjoying sports so much, and having faster development (Salvo et al., 2020; Guthold et al., 2020).

The correct way of carrying a backpack is to position the symmetrical straps over both shoulders and place the backpack at the level of T12 with a load of 10 % of body weight (Chen and Mu, 2018; Noll et al., 2016a,b; Brzek et al., 2017). These recommendations prevent postural changes and back pain (Brzek et al., 2017; Noll et al., 2016a,b). In this study, 52.5 % of participants carried the backpack correctly before the intervention. After intervention and ergonomic guidelines, 98.75 % started to carry the school backpack correctly. As for backpack weight,

26.25 % had more than 10 % of their body weight. These findings show that the pre-adolescents assimilated the ergonomic guidelines and started to carry the backpack correctly. Blanco-Morales et al. (2020) presented similar results for the students participating in the ergonomics workshop. These data suggest the need for assessing back pain and the weight and way children and adolescents, especially girls, carry their backpacks to develop and consolidate healthy habits through ergonomic guidelines and physical activity programs, since there is a gradual decline in several physical activity domains at this stage of life.

The main limitation for this study is the relatively small sample size due to the high number of school absences by pre-adolescents during the school year, which limited our power to detect significant group effects. Another limitation was the lack of adequate structure for practical classes in some schools since some classes were held in an open space with people circulating, in a dirty classroom, and with torn and old mats. Failing to investigate the back pain region of the pre-adolescents and identical sequence of movements proposed and not considering the individual needs of each participant were also limitations.

The public school is an appropriate environment to develop school health projects, and physical activity programs can improve healthy lifestyle habits in elementary school students that continue until adulthood.

5. Conclusion

Eutony, Holistic Gymnastics, and Pilates body practices increased hamstring flexibility and reduced back pain complaints. Moreover, the participants assimilated the guidelines on the correct way to carry their backpacks.

Acknowledgments funding

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior- Brasil (CAPES) – Finance Code 001.

Ethics committee

The State University of Campinas, Campinas, Brazil, under approval No.1869.831/CAEE 61623316.1.0000.5404.

Clinical relevance

As pre-adolescents have a sedentary lifestyle, back pain and reduced flexibility that may favor future pathologies, it is important to encourage and make accessible various forms of physical activity such as Eutonia, Holistic Gymnastics and Pilates. In this study, body practices increased the flexibility of hamstrings, reduced complaints of back pain and increased the number of participants who carried the backpack correctly. In addition, regular physical activity promotes the development of healthy habits for adult life.

We propose the continuation of this study through assessments of flexibility and back pain identifying the painful region, reinforcements of theoretical content of daily activities, so that the pre-adolescents can effectively incorporate the appropriate habits in everyday life, both at school and at home.

CRediT authorship contribution statement

Fernanda dos Santos Lopes Niaradi: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft, Writing – review & editing. **Maíra Fonseca dos Santos Lopes Niaradi:** Investigation, Resources. **Maria Elisabete Rodrigues Freire Gasparetto:** Conceptualization, Methodology, Project administration, Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Fernanda dos Santos Lopes Niaradi, Maira Fonseca dos Santos Lopes Niaradi, Maria Elisabete Rodrigues Freire Gasparetto.

References

Assiri, A., Mahfouz, A.A., Awadalla, N.J., Abolyazid, A., Shalaby, M., Abogamal, A., Alsabaani, A., Riaz, F., 2019. Classroom furniture mismatch and back pain among adolescent school children in Abha city, southwestern Saudi Arabia. Int. J. Environ. Res. Publ. Health 16, E1395. https://doi.org/10.3390/ijerph1608139.

Bazett-Jones, D.M., Rathleff, M.S., Holden, S., 2019. Associations between number of pain sites and sleep, sports participation, and quality of life: a cross-sectional survey of 1021 youth from the Midwestern United States. BMC Pediatr. 19, 201. https://doi.org/10.1186/s12887-019-1576-6.

Beynon, A.M., Hebert, J.J., Lebouef-Yde, C., Walker, B.F., 2019. Potential risk factors and triggers Fabricant for back pain in children and young adults. A scoping review, part II: unclear or mixed types of back pain. Chiropr ManTherap 27, 61. https://doi.org/10.1186/s12998-019-0281-8.

Blanco-Morales, M., Abuín-Porras, V., Romero-Morales, C., Cueva-Reguera, M., De-La-Cruz-Torres, B., Rodríguez-Costa, I., 2020. Implementation of a classroom program of physiotherapy among Spanish adolescents with back pain: a collaborative study. Int. J. Environ. Res. Publ. Health 17 (13), 4806. https://doi.org/10.3390/ijerph17134806.

Bland, J.M., Altman, D.G., 1997. Statistics notes: cronbach's alpha. BMJ 314, 572. https://doi.org/10.1136/bmj.314.7080.572.

Brodersen, A., Pedersen, B., Reimers, J., 1994. Incidence of complaints about heel-, knee- and back-related discomfort among Danish children, possible relation to short muscles. Ugeskr Laeger 156 (15), 2243–2245. https://doi.org/10.1080/17461391.2011.606833. PMID:8016952.

Brzek, A., Dworrak, T., Strauss, M., Sanchis-Gomar, F., Sabbah, I., Dworrak, B., Leischik, R., 2017. The weight of pupils' schoolbags in early school age and its influence on body posture. BMC Muscoskel. Disord. 18, 117. https://doi.org/10.1186/s12891-017-1462-z.

Chen, Y.L., Mu, Y.C., 2018. Effects of backpack load and position on body strains in male schoolchildren while walking. PLoS One 13, e0193648. https://doi.org/10.1371/journal.pone.0193648.

Condessa, L.A., Chaves, O.C., Silva, F.M., Malta, D.C., Caiaffa, W.T., 2019. Fatores socioculturais associados a atividade física de meninos e meninas: PeNSE 2012. Rev. Saude Publica 53, 25. https://doi.org/10.11606/S1518-8787.2019053000516.

Cureau, F.V., Silva, T.L.N., Bloch, K.V., Fujimori, E., Belfort, D.R., Carvalho, K.M.B., Leon, E.B., Vasconcellos, M.T.L., Ekelund, U., Schaan, D., 2016. ERICA: inatividade física no lazer em adolescentes brasileiros. Rev. Saude Publica 50 (1), 4s. https://doi.org/10.1590/S01518-8787.2016050006683.

Czaprowski, D., Leszczewska, J., Kolwicz, A., Pawłowska, P., Kędra, A., Janusz, P., Kotwicki, T., 2013. The comparison of the effects of three physiotherapy techniques on hamstring flexibility in children: a prospective, randomized, single-blind study. PLoS One 8 (8), e72026. https://doi.org/10.1371/journal.pone.0072026.

Dissing, K.B., Hartvigsen, J., Wedderkopp, N., Hestbaek, L., 2018. Conservative care with or without manipulative therapy in the management of back and/or neck pain in Danish children aged 9-15: a randomized controlled trial nested in a school-based cohort. BMJ Open 8 (9), e021358. https://doi.org/10.1136/bmjopen-2017-021358.

Donahoe-Filmore, B., Grant, E., 2019. The effects of yoga practice on balance, strength, coordination and flexibility in healthy children aged 10-12 years. J. Bodyw. Mov. Ther. 23 (4), 708–712. https://doi.org/10.1016/j.jbmt2019.02.007.

Dullien, S., Grifka, J., Jansen, P., 2018. Cluster-randomized, controlled evaluation of a teacher led multi factorial school-based back education program for 10 to 12-year old children. BMC Pediatr. 18, 312. https://doi.org/10.1186/s12887-018-1280-y.

Fabricant, P.D., Heath, M.R., Schachne, J.M., Doyle, S.M., Green, D.W., Widmann, R.F., 2020. The epidemiology of back pain in American children and adolescents. Spine 45 (16), 1135–1142. https://doi.org/10.1097/BRS.0000000000003461.

Fatima, G., Qamar, M.M., Hassan, J.U., Basharat, A., 2017. Extended sitting can cause hamstring tightness. Saudi J Sports Med 17 (2), 110–114. https://doi.org/10.4103/sjsm.sjsm_5_17.

Feldman, D.E., Shrier, I., Rossignol, M., Abenhaim, L., 2001. Risk factors for the development of low back pain in adolescence. Am. J. Epidemiol. 154 (1), 30–36. https://doi.org/10.1093/aje/154.1.30.

Ferreira, E.A.G., Duarte, M., Maldonado, E.P., Burke, T.N., Marques, A.P., 2010. Postural Assessment software (PAS/SAPO): validation and reliability. Clinics 65, 675e681. https://doi.org/10.1590/S1807-59322010000700005.

Fisk, J.W., Baigent, M.L., Hill, P.D., 1984. Scheuermann's disease. Clinical and radiological survey of 17- and 18-year-olds. Am. J. Phys. Med. 63 (1), 18–30.

Gajdosik, R.L., Albert, C.R., Mitman, J.J., 1994. Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. J. Orthop. Sports Phys. Ther. 20 (4), 213–219. https://doi.org/10.2519/jospt.1994.20.4.213.

Garber, C.E., Blissmer, B., Deschenes, M.R., Franklin, B.A., Lamonte, M.J., Lee, I.M., Nieman, D.C., Swain, D.P., 2011. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy

adults: guidance for prescribing exercise. Med. Sci. Sports Exerc. 43 (7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb.
Golle, K., Muehlbauer, T., Wick, D., Granacher, U., 2015. Physical fitness percentiles of German children aged 9–12 Years: findings from a longitudinal study. PLoS One 10 (11), e0142393. https://doi.org/10.1371/journal.pone.0142393.
González-Gálvez, N., Poyatos, M.C., Pardo, P.J.M., Vale, R.G.S., Feito, Y., 2015. Effects of s Pilates school program on hamstrings flexibility of adolescents. Rev Bras Med Esporte 21 (4), 302–307. https://doi.org/10.1590/1517-869220152104145560.
González-Gálvez, N., Marcos-Pardo, P.J., Carrasco-Poyatos, M., 2019. Functional improvements after a pilates program in adolescents with a history of back pain: a randomized controlled trial. Compl. Ther. Clin. Pract. 35, 1–7. https://doi.org/10.1016/j.ctcp.2019.01.006.
González-Gálvez, N., Vaquero-Cristóbal, R., Marcos-Pardo, P.J., 2020a. Effect of Pilates Method on muscular trunk endurance and hamstring extensibility in adolescents during twelve weeks training and detraining. J. Bodyw. Mov. Ther. 24 (2), 11–17. https://doi.org/10.1016/j.jbmt.2020.02.002.
González-Gálvez, N., Marcos-Pardo, P.J., Trejo-Alfaro, H., Vaquero-Cristóbal, R., 2020b. Effect of 9-month Pilates program on sagittal spinal curvatures and hamstring extensibility in adolescents: randomised controlled trial. Sci. Rep. 10 (1), 1–8. https://doi.org/10.1038/s41598-020-66641-2.
González-Gálvez, N., Vaquero-Cristóbal, R., Trejo-Alfaro, H., Marcos-Pardo, P.J., 2020c. Sagittal alignment of the spine and hamstring extensibility with Pilates in adolescents: protocol for randomized controlled trial. Eur. J. Integr. Med. 35, 101075 https://doi.org/10.1016/j.eujim.2020.101075.
Guariglia, D.A., Pereira, L.M., Pereira, L.M., Pereira, H.M., Cardoso, J.R., 2011. Reliability and usability assessment of three different softwares for photogrammetric analysis of hip flexion angle. Fisioter. Pesqui. 18 (3), 247–251. https://doi.org/10.1590/S1809-29502011000300008.
Guthold, R., Stevens, G.A., Riley, L.M., Bull, F.C., 2020. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based survey with 1-6 million participants. Lancet Child Adolesc Health 4 (1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2.
He, H., Pan, L., Du, J., Liu, F., Jin, Y., Ma, J., Wang, L., Jia, P., Hu, Z., Shan, G., 2019. Muscle fitness and its association with body mass index in children and adolescents aged 7-18 years in China: a cross-sectional study. BMC Pediatr. 19 (1), 19–101. https://doi.org/10.1186/s12887-019-1477-8.
Hernández, T.L., Ferré, M.C., Martí, S.G., Salvat, I.S., 2020. Relationship between school backpacks and musculoskeletal pain in children 8 to 10 Years of age: an observational, cross-sectional and analytical study. Int. J. Environ. Res. Publ. Health 17, 2487. https://doi.org/10.3390/ijerph17072487.
Jóźwiak, M., Pietrzak, S., Tobjasz, F., 1997. The epidemiology and clinical manifestations of hamstring muscle and plantar foot flexor shortening. Dev. Med. Child Neurol. 39 (7), 481–483. https://doi.org/10.1111/j.1469-8749.1997.tb07468.x.
Kedra, A., Kolwicz-Ganco, A., Sitarski, D., Kedra, P., Czaprowski, D., 2019. Prevalence of back pain and the knowledge of preventive measures in a cohort of 11619 Polish school-age children and youth-an epidemiological study. Medicine 98 (22), e15729. https://doi.org/10.1097/MD.0000000000015729.
Kim, H., Shin, W., 2020. Immediate effects of myofascial release using vibration foam rolling methods on hamstrings range of motion, flexibility, pressure pain thresholds and dynamic balance. J Int Acad Phys Ther Res 11 (2), 2042–2051. https://doi.org/10.20540/jiaptr.2020,11.2.2042.
Le Sant, G., Ates, F., Brasseur, J.-L., Nordez, A., 2015. Elastography study of hamstring behaviors during passive stretching. PLoS One 10 (9), e0139272. https://doi.org/10.1371/journal.pone.0139272.
Lima, T.R., Martins, P.C., Moraes, M.S., Silva, D.A.S., 2019. Associação da flexibilidade com fatores sociodemográficos, atividade física, força muscular e aptidão aeróbia em adolescentes do sul do Brasil. Rev Paul Pediatr 37 (2), 202–208. https://doi.org/10.1590/1984-0462/2019;37;2;00005.
Liyanage, E., Krasilshchikov, O., Hashim, H.A., Jawis, N.M., 2020. Prevalence of hamstring tightness and hamstring flexibility of 9-11 years old children of different obesity and physical activity levels in Malaysia and Sri Lanka. Journal of Physical Education and Sport 20 (1), 338–343. https://doi.org/10.7752/jpes.2020.s1047.
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. J. Sports Sci. Med. 13 (1), 1–14.
Mwaka, E.R., Munabi, I.A., Buwembo, W.I., Kukkiriza, J.O., Ochieng, J.O., 2014. Musculoskeletal pain and school bag use: a cross-sectional study among Ugandan pupils. BMC Res 7, 222.
Mikkelsson, L.O., Nupponen, H., Kaprio, J., Kautiainen, H., Mikkelsson, M., Kujala, U.M., 2006. Adolescent flexibility, endurance strength, and physical activity as predictors of adult tension neck, low back pain, and knee injury: a 25 year follow up study. Br. J. Sports Med. 40 (2), 107–113. https://doi.org/10.1136/bjsm.2004.017350.
Niaradi, F.S.L., Batista, C.G., 2018. Effect of Holistic Gymnastics in the flexibility of girls between 10 and 12 years. J. Phys. Educ. v29 https://doi.org/10.4025/jphyseduc.v29i1.2954.
Niaradi, F.S.L., Gasparetto, M.E.R.F., Niaradi, M.F.S.L., 2022. Effect of Eutonia, Holistic Gymnastics and Pilates on body posture for pre-adolescent girl: randomized clinical trial. J. Bodyw. Mov. Ther. 30, 226–236. https://doi.org/10.1016/j.jbmt.2022.02.021.
Noll, M., Candotti, C.T., Rosa, B.N., Vieira, A., Loss, J.f., 2021. Back pain and its risk factors in Brazilian adolescents: a longitudinal study. Br. J. Pain 15 (1), 16–25.
Noll, M., Candotti, C.T., Rosa, B.N., Loss, J.F., 2016a. Back pain prevalence and associated factors in children and adolescents: an epidemiological population study. Rev. Saude Publica 50, 31. https://doi.org/10.1590/S1518-8787.2016050006175.
Noll, M., Candotti, C.T., da Rosa, B.N., Sedrez, J.A., Vieira, A., Loss, J.F., 2016b. Layout for assessing dynamic posture: development, validation, and reproducibility. Pediatr. Phys. Ther. 28 (4), 435e444. https://doi.org/10.1097/PEP.0000000000000292.
Noll, M., Candotti, C.T., Vieira, A., Loss, J.F., 2012. Back pain and body posture evaluation instrument (Back PEI): development, content validation and reproducibility. Int. J. Publ. Health 58 (4), 565e572. https://doi.org/10.1016/j.pmn.2017.10.005.
Salvo, D., Aguilar-Farias, N., Jauregui, A., Varela, A.R., 2020. Sex and age disparities in physical activity among Brazilian adolescents: nature or nurture? J Pediatr (Rio de Janeiro) 96 (1), 4–7. https://doi.org/10.1016/j.jped.2018.12.006.
Sands, W.A., Mc Neal, J.R., Penitente, G., Murray, S.R., Nassar, L., Jemni, M., Mizuguchi, S., Stone, M.H., 2016. Stretching the spines of gymnasts: a review. Sports Med. 46, 315–327. https://doi.org/10.1007/s40279-015-0424-6.
SAPO–Software para Avaliação Postural, 2016. BMClab-Laboratório de Biomecânica e Controle Motor [internet] São Bernardo do Campo. http://demotu.org/sapo/. (Accessed 9 June 2016), 2016.
Schubert, A., Januário, R.S.B., Casonatto, J., Sonoo, C.N., 2016. Aptidão física relacionada à prática esportiva em crianças e adolescentes. Rev Bras Med Esporte 22 (2), 142–146. https://doi.org/10.1590/1517-869220162202103473.
Takata, K., Takahashi, K., 1994. Hamstring tightness and sciatica in young patients with disc herniation. J Bone Joint Surg Br 76 (2), 220–224. PMID: 8113280.
van Middelkoop, M., Rubinstein, S.M., Kuijpers, T., Verhagen, A.P., Ostelo, R., Koes, B. W., van Tulder, M.W., 2011. A systematic review on the effectiveness of physical and rehabilitation intervention for chronic non-specific low back pain. Eur. Spine J. 20 (1), 19–39. https://doi.org/10.1007/s00586-010-1518-3.
Zawadka, M., Smolka, J., Skublewska-Paszkowska, M., Lukasik, E., Jablonski, M., Gawda, P., 2022. The influence of sedentary behaviour on lumbar-pelvic kinematics during squatting and forward bending among physically active students. Ergonomics 1–12. https://doi.org/10.1080/00140139.2022.2061051.
Zhu, Q., Gu, R., Yang, X., Lin, Y., Gao, Z., Tanaka, Y., 2006. Adolescent lumbar disc herniation and hamstring tightness: review of 16 cases. Spine 31 (16), 1810–1814. https://doi.org/10.1097/01.brs.0000226047.83475.e4.