Original Article (short paper)

Effectiveness of mat Pilates on postural alignment in the sagittal plane in school children: a randomized clinical trial

Fabíola Unbehaun Cibinello[1], Jessica Caroliny de Jesus Neves[1], Mônica Yosino Leão Carvalho[1], Paola Janeiro Valenciano[1], Dirce Shizuko Fujisawa[1]

[1]*Universidade Estadual de Londrina, PR, Brasil.*

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Abstract - aims: This study aimed to investigate the effectiveness of the mat Pilates method, an exercise program, on postural alignment in the sagittal plane among children aged between 8 and 12 years**. Method:** This study used a blind randomized controlled clinical trial, with a Pilates group (PG) and control group (CG) at the Early Childhood Education Institute. A total of 40 children were randomized, who have no prior knowledge of the Pilates method and no exercise training in the last six months. Mat Pilates exercises were administered twice a week for four months in 50-minute sessions**.** Postural alignment in the sagittal plane was assessed using photogrammetry**. Results:** There was no statistically significant difference between the groups post-intervention A significant difference was found in the following outcomes that represent an improvement in intragroup postural alignment: among the children in PG, in the right sagittal view in the vertical body alignment (p=0.019; effect size, ES = 0.70; standardize response mean, SRM = 0.57) and in the sagittal head angle (p=0.035; ES = 0.41; SRM = 0.51). Among the children in the CG, in the vertical alignment of the trunk in the left sagittal view (p= 0.016; ES = 0.50; SRM = 0.44). **Conclusion:** The effectiveness of Pilates on postural alignment in the sagittal plane among children aged between 8 and 12 years was not confirmed.

Keywords: exercise movement technics; Pilates-based exercises; child; posture; school.

Introduction

Posture typically refers to the alignment of body segments at a specific time. Incorrect posture refers to an abnormal body state in which the body cannot maintain a stable state and the normal function of tissues and organs are compromised[1,2]. Postural control requires an integration of sensory information with the musculoskeletal system. Correct postural alignment allows postural control to be achieved with the least possible energy expenditure. In the ideally aligned posture for an average adult, the center of gravity is slightly anterior to the first or second sacral segment[3]. Posture can be influenced by multiple factors, including heredity, lifestyle, emotional and socioeconomic factors, and growth and development[4].

During childhood and adolescence, considerable changes can be observed in postural alignment and mobility[5]. School-aged children are exposed to factors that can influence postural alignment. Previous studies have investigated the possible relationship between school backpack load and postural changes and pain perception[6]. Additionally, a systematic review concluded that sagittal alignment during sitting and standing should be further investigated as possible risk factors for adolescent neck pain and mid-back pain[7].

Previous studies showed that a positive relationship is found between physical activity and posture. Children with a high level of physical activity show less body tilt compared to those with a low level of activity[8]. Physical activity was also associated with a lower prevalence of valgus knee among children[9].

To achieve the benefits of physical activity, children and adolescents should participate for at least 60 minutes of moderate to vigorous physical activity daily[10]. Children spend most of their time in the school environment, so this environment must offer opportunities that increase the time of physical activity in this population. Previous studies showed that time spent in physical activity is higher on days when children attend school[11,12].

Pilates is an exercise method that aims to integrate the whole body. It is a type of structured physical activity that can be applied to any population, including children and adolescents, and can be easily inserted into the school environment. The exercises are designed to achieve postural symmetry, breathing control, abdominal strength, and stabilization of the spine, pelvis, and shoulder. It also proposes that children need to know their bodies[13].

The Pilates method is expected to promote greater postural alignment in the sagittal plane since the exercises seek symmetry and stabilization of the posture. In the adult population, a systematic review concluded that evidence shows that the Pilates method is useful among healthy individuals to improve flexibility, dynamic balance, and endurance. However, the results were inconclusive as regards postural alignment. This study highlights the low methodological quality of the studies found[14]. In the population of children and young people, systematic review findings showed that Pilates does seem to improve flexibility; muscle strength, power, and movement speed; postural control, orientation, and balance; metabolic cost; and functional ability and health-related quality of life and reduce pain in children with musculoskeletal pathology. However, the authors pointed out that methodological quality varied across studies, highlighting the need for further research using well-designed clinical trials to confirm effectiveness for specific population groups and to establish the ideal frequency, duration, and model of treatment[15].

In clinical practice, although the Pilates method is widely used among children, both as a form of structured physical activity and as a treatment for various conditions, among them the postural changes, the evidence is still lacking in the literature regarding its benefits. Therefore, this study aimed to investigate if a mat Pilates exercise program, carried out in groups and within the school environment, promotes better postural alignment in the sagittal plane among children aged between 8 and 12 years, compared with the results obtained in children who participated in the program with a control group. The study hypothesizes that the intervention program promotes improvement in the alignment of the head, trunk, and lower limbs.

Method

Study design

This study was a blind randomized controlled clinical trial conducted between July 2017 and June 2018. The intervention included mat pilates exercises twice a week for approximately 4 months (28 sessions). Assessments were performed in the pre- and post-intervention periods in the control group (CG) and Pilates group (PG) during the week before the beginning of the program and during the week after the end of the program, respectively. The study was carried out at the Early Childhood Education Institute, Londrina, PR, Brazil. The protocol was inserted in the school environment as part of an extracurricular and nonmandatory activity, carried out outside the class period.

The study was registered in the Brazilian Registry of Clinical Trials in May 2017 (No. RBR-8t5p7d). All methodological procedures followed the recommendations of the Consolidated Standards of Reporting Trials[16]. The research project was approved by the Human Research Ethics Committee of the State University of Londrina (No. 1974596). Written informed consent was obtained and signed by the parent or guardian. At the end of the study, the assessments were given to the parent/guardian, and if necessary, they were referred to the Basic Health Unit.

Randomization

Recruitment was done through informative posters in schools, churches, and buses, as well as publications in social media. The selected participants were randomly assigned using a random number table generated by random.org and divided into two groups: CG and PG. Sealed opaque envelopes containing cards labeled “CONTROL” and “PILATES” were used to ensure concealed distribution. The procedure was performed using the software program by a researcher who did not know the objectives and purposes of the study.

Blinding

The assessors were blinded to the distribution of participants to CG and PG in the pre- and post-intervention assessments. Participants were not informed of the study hypothesis and were instructed not to talk to the assessors about the technical aspects of the study. Photogrammetry images were analyzed by the assessors who entered the data in the spreadsheets also in a blinded manner.

Participants

The inclusion criteria included children aged between 8 and 12 years, with no prior knowledge of the Pilates method and no physical training in the last six months. The exclusion criteria included chronic disease, musculoskeletal disorder, recent surgery, inability to maintain orthostatic position, physical and/or sensory deficit, dizziness or vertigo, attention deficit, and continuous use of medication.

Intervention

The exercise program was formulated based on books[13,17,18] and materials and handouts acquired in Pilates method training courses. The proposed intervention program was submitted for assessment by three physical therapists with extensive experience in the Pilates method. For more information, consult the intervention protocol available in the supplementary material.

The intervention was performed in 28 sessions, with each session lasting approximately 50 minutes. The first session consisted of familiarization with the method and its principles. Using a playful approach, children were instructed on breathing, correct positioning of the spine and limbs, and contraction of the abdominal muscles, gluteal muscles, and adductors during the exercises. The following sessions were composed of 10 exercises which were performed in the following order: bridging, book opening, single-leg stretch, rolling like a ball, swan, swimming, quadruped, mermaid, spine stretch forward and standing roll down. The intervention protocol considered the overall work of the body and the inclusion of exercises that could easily be adapted to the school environment.

The progression of movements was achieved via the number of repetitions and speed. During the first sessions, six to eight repetitions of each movement were performed at a slow speed. From the 12th session, 10 to 12 repetitions were performed at a higher speed. The speed was controlled by the instructor’s count, which induced the rhythm of the exercises according to the command voice. In addition, for some exercises, the degree of difficulty of execution was increased, e.g., from bilateral to unilateral support in the bridging exercise.

The language used was adapted for the age group between 8 and 12 years. For ease of understanding, mental images were provided for each exercise (e.g., position yourself on all fours, like a cat). To facilitate the understanding of the correct position of the spine, a long stick was used to support the back. The feet were marked with colored stickers in three places (head of the first and fifth metatarsus and calcaneal region) in order to facilitate the explanation of the correct distribution of plantar pressure. Each session started with a playful activity, which sought to teach some principles of the Pilates method, such as playing with a wind vane and learning about breathing.

Each child should attend at least 90% of the sessions (maximum of 2 absences). When the child has exceeded the number of absences allowed, the child was considered a dropout. The intervention was performed by a single physical therapist trained in the Pilates method, and the groups consisted of a maximum of eight children. The Pilates sessions were also supported by five previously trained physical therapy students who assisted in correcting the exercises (way of executing the movement, identifying compensations and errors in the realization).

Control group

The CG performed the assessments at the same time as the PG. During the PG intervention period, the CG was monitored by phone, to confirm continuity of participation in the project, and received no treatment or guidance on posture. During this period, the children participated in physical education classes, as mandated in the school curriculum. After the post-intervention assessment, the CG received the same intervention as the PG.

Assessment and outcomes

The postural alignment was assessed using photogrammetry. The images were obtained using a digital camera (Nikon® COOLPIX P510, 16.1 megapixels) mounted on a tripod (WF®, model wt-3510A) 90 cm above the ground, 300 cm from the child, and 350 cm from the wall. The participants were placed in front of a nonreflective black background and standing on an EVA carpet (30 cm × 35 cm). They were dressed in swimwear, standing in the orthostatic position with arms to the side of the body, feet slightly apart, and weight equally distributed[19]. Photographs were taken in the frontal (anterior and posterior views) and the left and right sagittal planes. The following anatomical landmarks were marked with Styrofoam balls: glabella, tragus, acromion, C7 spinous process, lower angle of the scapula, T3 spinous process, anterior superior iliac spine, posterior superior iliac spine, major femoral trochanter, knee, medial point of the patella, tuberosity of the tibia, point on the midline of the leg, lateral malleolus, medial malleolus, point on the calcaneus tendon at the malleolus, calcaneus, and point between the head of the second and third metatarsals. The materials used were as follows: tape measure, 15 mm white Styrofoam balls for marking the anatomical landmarks, plastic rods which were 8 mm in diameter and 5.5 cm in length for marking the spinous processes for better lateral visualization, and double-sided adhesive tape. The vertical reference was obtained using a tape measure cut in 10 cm and fixed vertically on the child in all of the views. In the sagittal view, the participants were asked to flex the elbow at 90° to show the marker on the anterior superior iliac spine. The horizontal alignment of the floor, the tripod, and the machine was measured with a wooden level [20-22].

The images were scanned using an image processing software program (Sapo®) with 100% zoom and calibration of the photos. The following variables were analyzed in the sagittal plane following the Sapo® protocol: horizontal head alignment (HHA), vertical head alignment (VHA), vertical trunk alignment (VTA), hip angle (HA), vertical body alignment (VBA), horizontal pelvic alignment (HPA), knee angle (KA), and center of gravity–asymmetry in the sagittal plane (SCG) and frontal plane (FCG)[23,24]. Other analyses were also carried out in the sagittal plane: shoulder angle (SA) to verify shoulder protraction or retraction[3,25], sagittal head angle (SHA) with greater anterior angles indicating greater cervical extension[3,25], and forward head distance (FHD), with high values indicating forward head posture[3,26]. Figure 1 shows these variables. Data collection was performed by a single assessor, who has training and experience in photogrammetry with the child population, at all stages: placing markers, obtaining images, and analysis using the Sapo® software[27-29].

Sample size

The estimated sample was seven participants in each group, considering the mean difference of 2.1° in VBA, according to Goulart et al.[30] and an alpha of 95% and a beta of 80%[31]. However, 20 individuals were included in each group to allow for any losses.

Statistical analysis

Statistical analysis was performed using GraphPad Prism® 6. The normality of the data was evaluated using the Shapiro–Wilk test, and the results are presented as mean ± standard deviation or median and quartiles. Intragroup comparisons were performed using the Student T-test (paired) or Wilcoxon test. Intergroup comparisons were performed using the Student T-test (unpaired) or Mann–Whitney test. Responsiveness was analyzed to determine the magnitude of the changes by calculating the effect size (ES) and standardized response mean (SRM). Values can be interpreted as small (≤0.2 to 0.4), moderate (0.05 to 0.7), or large (≥0.8)[32]. Significance was set at $p < 0.05$, using the intention-to-treat analysis.

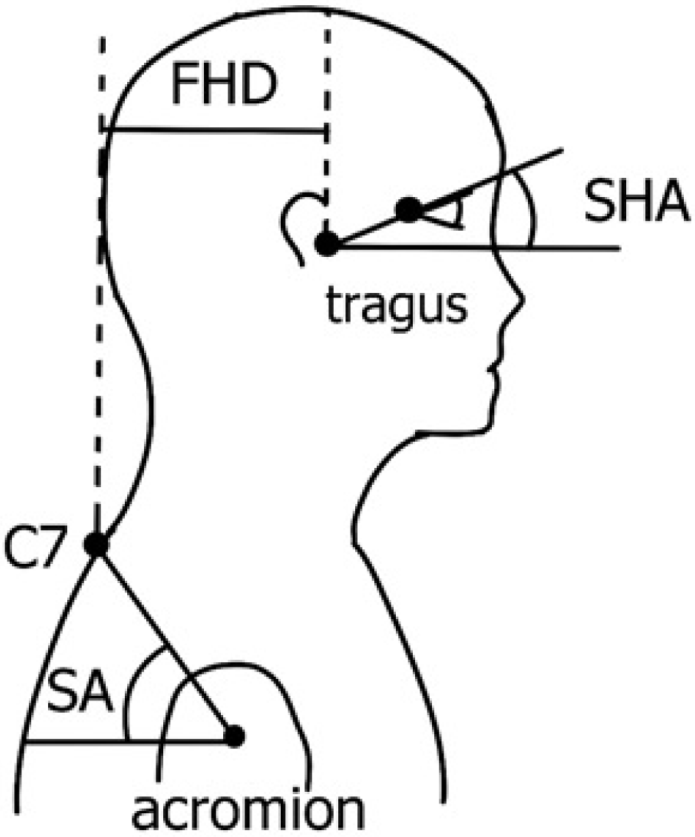

Figure 1- Variables assessed by photogrammetry. SA- shoulder angle; SHA- sagittal head angle; FHD- forward head distance
Source: Adaptation from Camargo (2018)

Results

The study included 43 children selected based on the eligibility criteria. Three children were excluded before randomization, while 12 children were excluded during the protocol (PG, n = 7; CG, n = 5). The dropout rate was 35% in PG and 25% in CG. At the end of the study, the data of 40 participants were analyzed, including those who have not completed the protocol. The results of this analysis are described below. For comparison purposes, the protocol analysis was also performed (considering only the participants who completed the protocol), with no changes in the results. Figure 2 shows the flowchart for the participants.

The groups had similar baseline data regarding age, gender, and height. In contrast, body mass and body mass index were significantly higher in the PG ($p = 0.010$) (Table 1) than in the CG. In the post-intervention assessment, body mass and BMI remained significantly higher in PG ($p = 0.011$ and $p = 0.012$ respectively) than in the CG.

During the initial postural assessment, the groups were heterogeneous regarding the variables SA ($p = 0.033$) and SHA ($p = 0.041$) in the left sagittal view, with the PG showing a smaller angle in both. No statistically significant difference was observed in posture measures between the post-intervention groups. Table 2 shows the results of the intragroup and intergroup postural assessments.

In the right sagittal view, a significant difference was found in VBA between the pre- and post-intervention assessments in the PG, as it neared 0° (ES = 0.70, SRM = 0.57). A significant difference was found in the SHA variable between the pre- and post-intervention assessments in the PG, with a greater angle and greater cervical extension after the intervention (ES = 0.41, SRM = 0.51).

In the left sagittal view, a significant difference was also found in VBA between the pre-and post-intervention assessments in the PG, but moving away from 0° (ES = 0.76, SRM = 0.50). A significant difference was found in VTA in the CG, and the values neared 0° (ES = 0.56; SRM = 0.44).

Regarding the center of gravity, no significant intragroup and intergroup differences were found (Table 3). No adverse effects were reported.

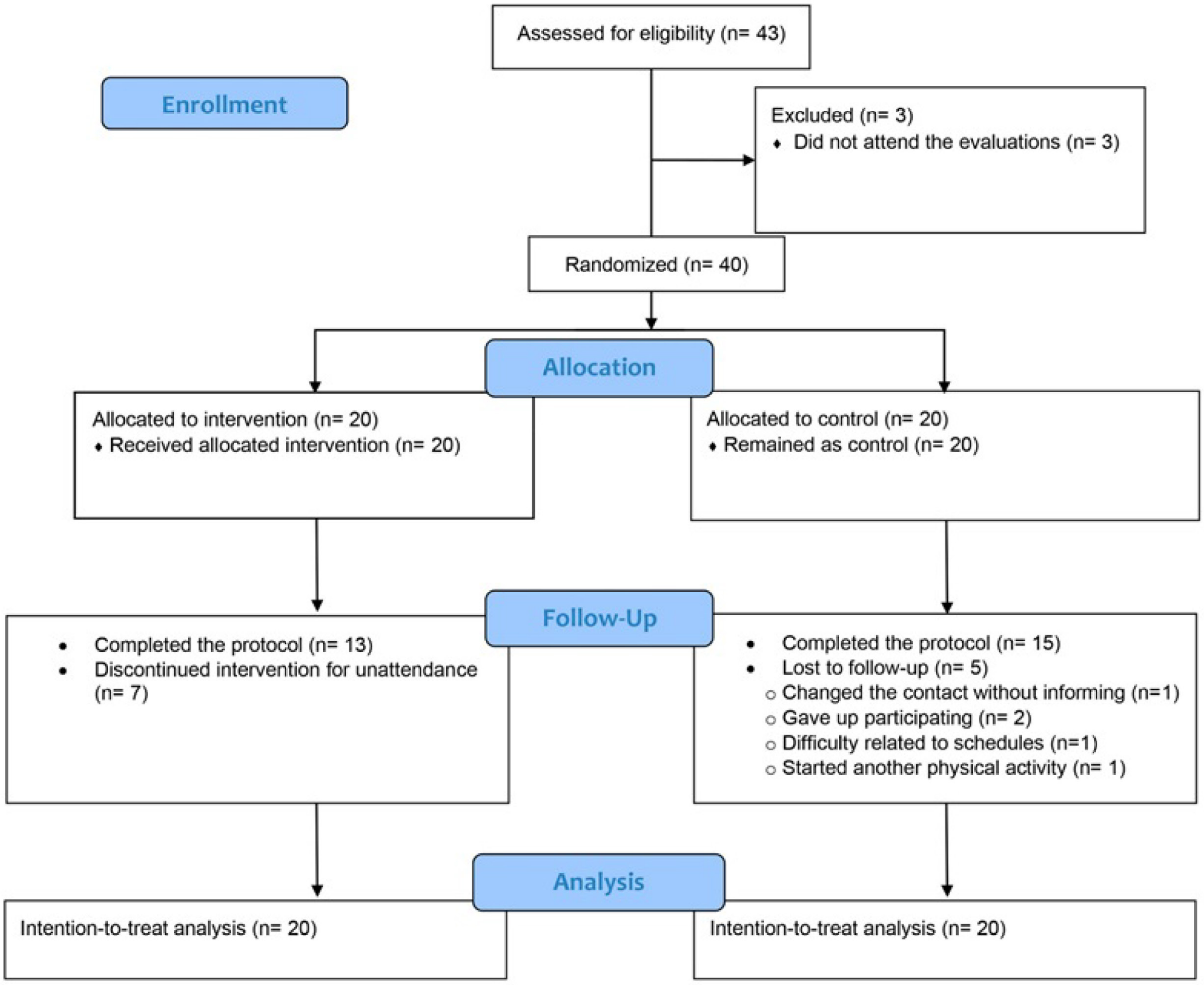

Figure 2 - Flowchart of participants at each stage of the study

Table 1 - Characteristics of Participants

	PG	**CG**	**p**
Age	10 (8.2-11)	9 (8.2-10)	0.34
Male (%)	3(15)	3(15)	
Female (%)	17(85)	17(85)	
Body mass (kg)	45.70 ± 11.30	37.30 ± 10.30	0.010*
Height (cm)	145.90 ± 10.00	141.70 ± 10.40	0.20
BMI (kg/m²)	21.32 ± 4.10	18.24 ± 2.90	0.010*

* $p < 0.05$; P-value according to the T-test (unpaired) or Mann-Whitney test.
Results are presented as mean ± standard deviation or median and quartiles.
BMI (Body mass index).

Table 2 - Postural Assessment- Comparison within and between groups

Variable	PG				CG				Between-group Comparison
	Pre	Post	Δ	p	Pre	Post	Δ	p	p
Right sagittal view									
HHA	47.36±5.53	47.46±5.71	0.10±5.85	0.94[a]	47.03±4.66	48.36±5.86	1.32±3.97	0.15[a]	0.41[c]
VHA	7.15 ± 8.61	7.47± 8.87	0.32±7.15	0.84[a]	2.88±1.49	2.17±1.64	0.28±6.27	0.84[a]	0.76[c]
VTA	0.00(-1.80 -1.27)	-1.05(-3.60 – 0.37)	0.00(-2.50 – 0.00)	0.05[b]	-1.45(-4.25 -1.87)	-1.30(-3.50 -0.00)	0.00(-2.50-0.58)	0.59[b]	0.53[d]
HA	-7.91± 4.65	-9.07± 4.97	-1.16±4.02	0.21[a]	-7.64± 5.93	-7.38± 4.72	0.26±2.84	0.69[a]	0.21[c]
VBA	3.65(2.12-4.00)	2.35(1.12-3.60)	0.00(-2.85– 0.15)	0.019[b]*	2.70(2.20 -4.22)	2.50(1.05 –3.15)	-0.15(-0.92 – 0.00)	0.11[b]	0.92[d]
HPA	-16.25(-19.08 –-11.88)	-14.15(-16.85- -11.78)	0.00(-0.98-3.88)	0.20[b]	-16.05(-20.53 - -10.65)	-13.35(-18.85 - -10.53)	0.00(-0.77 – 3.90)	0.23[b]	0.81[d]
KA	-4.84±4.64	-3.99±5.46	0.85±4.22	0.38	-5.46±5.05	-5.81±4.46	-0.35±1.90	0.43[a]	0.48[c]
FHD	8.71±1.22	8.51±1.25	-0.19±0.73	0.25[a]	8.44±1.19	8.24±1.28	-0.19±0.75	0.26[a]	1.00[c]
SA	14.95(6.60 – 22.45)	19.05(11.65 -24.7)	0.00(0.00 -5.97	0.13[b]	18.65(16.35 -24.68)	18.75(15.15 -30.90)	0.00(-1.97 – 3.37	0.40[b]	0.35[d]
SHA	10.85(4.80-13.00)	12.45 (8.97-17.55)	0.30(0.00-6.35	0.035[b]*	13.90(10.10 -18.83)	12.70(9.75 -17.38)	0.00(-5.37-4.90)	0.63[b]	0.08[d]
Left sagittal view									
HHA	49.40±5.20	48.11±4.99	-1.29±4.68	0.39[a]	49.04±4.33	48.22±4.18	-0.82±4.22	0.43[a]	0.83[c]
VHA	7.74±11.20	8.87±8.89	1.13±7.79	0.52[a]	8.46±7.73	6.69±7.94	-1.77±6.94	0.27[a]	0.32[c]
VTA	-2.70(-4.20 – -0.52)	-2.75(-4.60 - -0.25)	0.00(-0.45 – 1.60)	0.84[b]	-3.50(-4.55 - -1.20)	-1.90(-3.57 -0.55)	1.50(0.00 - 3.02)	0.016[b]*	0.20[d]
HA	-8.65(-11.78 – -2.35)	-9.30(-11.78 -6.30)	0.00(-4,52 - 0.00)	0.11[b]	-10.60(12.08 – -6.07)	-9.90(-11.55 - -6.90)	0.00(-1.10 - 1.90)	0.49[b]	0.06[d]
VBA	1.30 (-0.57 - 2.22)	2.00 (0.52 - 4.12)	0.10(0.00 - 3.42)	0.037[b]*	1.05(0.30 - 2.87)	2.10(0.67 – 3.92)	0.30(0.00 - 1.77)	0.06[b]	0.76[d]
HPA	-14.25(-17.23 – 10.45)	-15.15(-17.90 - -11.75)	0.00(-3.62 - 0.07)	0.34[b]	-14.55(-19.23 - -10.73)	-13.90(-18.85 – -8.95)	0.00(-2.37 – 3.17)	0.45[b]	0.30[d]
KA	-4.44±4.55	-5.60±3.27	-116±3,58	0.16[a]	-6.37±4.73	-7.02±4.72	-0.65±2.34	0.23[a]	0.60[c]
FHD	8.25(7.70 – 2.03)	8.85(7.82 – 9.15)	0.00(-0.42 - 0.75)	0.72[b]	8.15(7.35 -8.82)	7.90(7.32 – 8.70)	0.00(-0.37 -0.20)	0.39[b]	0.62[d]
SA	13.30(9.42 – 17.28)	14.40(10.55 -19.20	0.00(-2.92-2.97)	0.74[b]	20.85 (11.70 -28.43)	16.70(12.28 -24.63)	-1.35(-6.60 - 0.00)	0.24[b]	0.26[d]
SHA	10.15(5.35 – 16.85)	10.80(6.67 -17.25)	0.00(0.00 - 3.75)	0.17[b]	14.10(10.30 -21.28)	13.75(9.65 -20.33)	0.00(-3.65 - 1.35)	0.29[b]	0.13[d]

* p< 0,05. P-value according to the T-test (paired) a or Wilcoxon test b for intragroup comparisons, T-test (unpaired) c or Mann-Whitney test d for between-groups comparisons. Results are presented as mean ± standard deviation or median and quartiles.
HHA (horizontal head alignment), VHA (vertical head alignment), VTA (vertical trunk alignment), HA (hip angle), VBA (vertical body alignment), HPA (horizontal pelvic alignment), KA (knee angle), FHD (forward head distance), SA (shoulder angle), SHA (sagittal head angle).

Table 3 - Center of Gravity- Comparison within and between groups

Variable	PG				CG				Between-group Comparison
	Pre	Post	Δ	p	Pre	Post	Δ	p	p
FCG	-12.55(-27.90-2.35)	-0.80(-14.43- 8.80	0.55(0.00 - 21.90	0.09[b]	-9.45(-20.20 - 00.50)	-0.05(-14.78 - 9.90)	4.6(0.00 - 20.70	0.06[b]	0.66[d]
SCG	25.35(23.53-47.48)	32.85(23.35-47.43)	0.00(-0.97 - 3.15)	0.27[b]	35.85(20.65 - 39.33)	29.85(24.08 - 39.75)	0.00(-8.52 - 7.95)	0.84[b]	1.00[d]

* p< 0,05. P-value according to the Wilcoxon test b for intragroup comparisons, Mann-Whitney test d for between-groups comparisons. Results are presented as median and quartiles.
FCG (frontal plane), SCG (sagittal plane).

Discussion

No statistically significant differences were found in the postural alignment variables between the groups after the intervention. In the adult population, systematic reviews show inconclusive results on the effects of the Pilates method on postural alignment[14,33]. In children and adolescents, the pattern of alignment is more dynamic, which makes these effects even harder to identify. The developing individual has greater flexibility and mobility, which allows the occurrence of momentary and habitual deviations from alignment. Moreover, the structures of the body grow at varying speeds[34]. The child's postural alignment in the sagittal plane changes considerably between the ages of 4 and 12. Additionally, the postural changes found can be considered physiological and part of the process of growth and development. However, musculoskeletal conditions may occur in children if the threshold of a tolerable postural displacement is reached[5]. Therefore, individualized monitoring, different from what was carried out in this study, might be the best option to identify postural deviations in the child and to determine which alterations need intervention and which fall within the normal process of growth and development. Future studies are needed to evaluate the effects of individualized interventions and programs based on the Pilates method with specific exercises for the misalignments found in each child.

However, this study aimed to evaluate an intervention proposal based on the Pilates method that could be carried out in groups and easily inserted into the school environment. Moreover, the expectation that the overall bodywork proposed by the method (flexibility, muscle strengthening, postural control, breathing work)[13] would generate an improvement in postural alignment in the sagittal plane was not proven. If this happened, Pilates could be a preventive exercise proposed for children at risk of developing postural changes and pain due to daily activities such as watching television, sitting posture, and carrying the school backpack[35,36].

Some exercises were chosen for the protocol to generate activation of stabilizing muscles, which could bring benefits for postural alignment. Previous studies showed that the lumbopelvic stabilizer muscles are activated during the first session of Pilates and that activation is enough to lead to lumbopelvic stabilization and strengthening. One of the exercises that provides this activation is the single-leg stretch used in the protocol of the present study[37]. When trunk flexion is combined with the Pilates method of breathing, there is greater electrical activity of the transverse abdominis and internal oblique muscles, which are important spinal stabilizers[38]. Swimming exercise generates enough activation of the multifidus muscles to promote physiological changes, thus improving postural stability[39]. The possible reasons why this improvement in postural alignment has not been observed are discussed below.

The results of this study may be influenced by the fact that the PG and CG presented some differences during the first assessment. In the pre-intervention assessment, the groups were different in the variables SA ($p = 0.033$) and SHA ($p = 0.041$) in the left sagittal view. The PG had the smallest angle in variables, indicating greater shoulder protraction and lower cervical extension[3,25], i.e., worse shoulder and cervical alignment. In the post-intervention assessment, this difference was no longer found, with the values of PG increasing and CG decreasing in both variables, but without showing a statistically significant difference. Therefore, stating that these changes were caused by the intervention based on the Pilates method is not possible. In the right sagittal view, the SHA variable showed a significant difference between the pre- and post-intervention assessments in the PG, with an increase in cervical extension among the children who were part of the Pilates program, with small change and moderate responsiveness. This variable measures the alignment of the high cervical spine[25]. This result is important given that certain habits of school-aged children, such as carrying a school backpack, can affect the positioning of the head, leading to forwarding head posture[40]. The position of reading a book on the table can lead to flexed head and neck posture[41]. During Pilates exercises, the instructor must teach students to keep their head aligned with the rest of the spine with eyes facing forward[13]. These instructions were emphasized in the protocol of the present study, contributing to such results in the PG.

Children in the PG had significantly higher body mass and BMI than those in the CG in the pre- and post-intervention assessment, which may have affected postural alignment measures. Previous studies showed that a high BMI is associated with postural misalignments in the sagittal plane during childhood and adolescence, including posterior trunk tilt and decreased or increased thoracic kyphosis and lumbar lordosis[3,8,42]. Additionally, lower adiposity was associated with a flattened spine and concordantly, higher fat, and fat-free mass with a rounded posture type[43]. The higher BMI in the PG may have caused the improvement in the VTA variable in the intragroup assessment only in the CG. In the CG, post-intervention results in the left sagittal view showed improvement in VTA, with moderate change and small responsiveness. In the pre-intervention assessment, the values indicated the posterior tilt of the trunk. In the post-intervention assessment, the values approached the axis, i.e., there was the forward movement of the trunk. According to Lanfond[5], these postural changes are the result of musculoskeletal development during childhood and puberty, reflecting an adaptation process aimed at maintaining adequate sagittal balance and proper configuration in terms of musculoskeletal loads and curvature development in the sagittal plane.

In the post-intervention assessment, the PG continued with significantly higher BMI and body mass values than those of the CG. Therefore, the Pilates method did not influence the children's anthropometric measurements in this study. This result is similar to Hornsby's[15] systematic review that concluded that the Pilates method does not seem to affect anthropometric measurements in children. Another systematic review carried out with several populations concluded that the Pilates method is no better than the control condition or other types of training to reduce body composition[44].

VBA showed inverse results between the right and left sagittal views in the PG. In the right sagittal view, the values approached alignment, and the median in the pre-intervention assessment went from 3.65 (2.12–4.00) to 2.35 (1.12–3.60) in the post-intervention assessment, with small change and moderate responsiveness. In the left sagittal view, there was distancing from alignment at 0°, with a median of 1.30 (-0.57–2.22) in the pre-intervention assessment and 2.00 (0.52–4.12) in the post-intervention assessment, with moderate change and small responsiveness. The results show that the values of the right and left sagittal views moved closer at the end of the protocol, which may indicate better alignment, i.e., less rotation of the body axis. However, as no intergroup difference was found in this variable, stating that this improvement occurred due to an intervention based on the Pilates method is not possible.

Regarding the instrument used for postural assessment, photogrammetry is a viable, valid, and reproducible option for the assessment of postural alignment and has been widely used in scientific research. Photogrammetry facilitates the collection and detailed analysis of data, thus allowing the evaluation of the spine and other body segments in the sagittal and frontal planes[20-22]. The postural assessment software (Sapo®) was developed to aid in the assessment of posture from photos and is available in the public domain. Sapo® software is accurate in measuring angles and distances and is easy to use, as they are accompanied by tutorials. Previous studies showed that Sapo® has good inter- and intra-rater reliability, so its usefulness and reliability for measuring posture must be considered[23,27,28]. Sapo® software has proven to be a viable and reliable quantitative method for analysis also in children[29]. A systematic review concludes that evidence to support the use of photogrammetry in accompanying postural treatment is still lacking, whether for clinical or research purposes[20]. However, the same study showed that, when dealing with a collective health situation, such as groups of school-aged children, prioritizing simpler protocols for postural assessment is necessary[20].

A possible limitation of this study is the considered high dropout rate (35% in PG and 25% in CG). However, intention-to-treat analysis and protocol analysis showed the same results. In the previous studies, experimental studies that evaluate the effects of exercise programs in children with a dropout rate higher than 20% can still be found[45-47]. Children are dependent on their parents or guardians to be able to attend exercise sessions, so the dropout rate may be high when conducting studies with this population. During this study, the parents constantly reported on the difficulties of commuting and schedules. Although no instrument was used to measure participants' satisfaction, at the end of the project, the children reported having enjoyed the Pilates sessions. Another possible limitation of this study was the lack of follow-up of the sample to verify whether the observed differences remained after the end of the protocol.

Although a sample calculation was performed, it was based on a non-randomized clinical trial[30], as there were no similar studies to be taken as a basis. In addition, the sample used was part of a project that involved several clinical trials that did not reach the expected sample due to the low adhesion of volunteers. However, the sample calculation showed that this sample was sufficient for the outcomes analyzed in this study.

This is the first randomized controlled trial that evaluated postural alignment in the sagittal plane in children aged 8 to 12 years, in the school environment, with an intervention of approximately 4 months. Future studies may use this study as a basis for the sample calculation when evaluating the effectiveness of the Pilates method in children, as well as conducting a clinical trial with follow-up, to verify the permanence of the results.

Conclusion

There was an intragroup improvement in postural alignment in some outcomes in both groups. There is no statistically significant difference between the groups of Pilates and control post-intervention. Therefore, the effectiveness of Pilates on the postural alignment in the sagittal plane among children aged between 8 and 12 years was not confirmed. Mat Pilates is possible to be implemented within the school environment, with adapted language, playful elements, and group sessions.

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Corresponding author

Fabíola Unbehaun Cibinello
Universidade Estadual de Londrina, Centro de Pesquisa e Pós-graduação – CEP-POS. Avenida Robert Koch, n. 60, Vila Operária, 86039-440. Telephone: +55 (43) 3381-2000
Email: fabi.cibinello@hotmail.com

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