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Physical activity, sedentary time and bone tissue: effects of an 8-months interdisciplinary program with overweight/obese children

Atividade física, tempo sedentário e tecido ósseo: efeitos de um programa interdisciplinar de oito meses com crianças com sobrepeso/obesidade

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ABSTRACT

Moderate to vigorous physical activity plays a recognized osteogenic effect on bone. Moreover, sedentary time, and fat accumulation are unfavorable to bone health. Our study aimed (1) to examine changes in body composition, bone tissue, physical activity, and sedentary time; and (2) to explore whether changes in physical activity intensities and in sedentary time are associated with changes in bone outcomes after a school-based interdisciplinary intervention program. A total of 53 overweight/obese students (10.6 ± 3.5 year-olds; 26 girls) participated in physical activity classes. Bone area, bone mass, and bone mineral density z-score, body composition (fat mass, fat lean mass), physical activity, sedentary time and potential confounders (vitamin D and maturational status) were assessed at baseline, and 8 months later. General Linear Models were carried out and significance level was set at 5%. Changes in moderate to vigorous physical activity were positively correlated with changes in all bone mass indicators. We observed a significant overall effect of the intervention on bone mineral density z-score changes, however after adjustments for changes in sedentary time and moderate to vigorous physical activity, no effect was observed. Finally, variations in sedentary time and in moderate to vigorous physical activity play an important role in bone mass density in those participants of the interdisciplinary program.

Keywords: Motor activity; Sedentary lifestyle; Bones; Physical education.

RESUMO

A atividade física moderada-vigorosa tem efeito osteogênico reconhecido no osso. Além disso, o tempo sedentário e o acúmulo de gordura são desfavoráveis à saúde óssea. Este estudo objetivou: (1) examinar mudanças na composição corporal, tecido ósseo, atividade física e tempo sedentário; e (2) explorar se as mudanças nas intensidades de atividade física e no tempo sedentário estão associadas a mudanças nos resultados ósseos após um programa de intervenção interdisciplinar de base escolar. 53 estudantes com sobrepeso/obesidade (10,6 ± 3,5 anos; 26 meninas) participaram de aulas com atividade física. Área óssea, massa óssea e escore z de densidade mineral óssea, composição corporal (massa gorda, massa magra de gordura), atividade física, tempo sedentário e potenciais confundidores (vitamina D e status maturacional) foram avaliados no início e após 8 meses. Modelos Lineares Generalizados foram realizados e o nível de significância foi estabelecido em 5%. Alterações na atividade física moderada-vigorosa foram positivamente correlacionadas com as mudanças em todos os indicadores de massa óssea. Observou-se um efeito geral significativo da intervenção nas alterações do escore z de densidade mineral óssea, entretanto, após ajustes para mudanças no tempo sedentário e atividade física moderada-vigorosa, nenhum efeito foi observado. Por fim, variações no tempo sedentário e na atividade física moderada a vigorosa desempenham importante papel na densidade da massa óssea nos participantes do programa interdisciplinar.

Palavras-chave*: Atividade motora; Estilo de vida sedentário; Ossos; Educação física.*

Introduction

Some behaviors, such as low levels of physical activity and increased sedentary time, are important public health problems[1]. In this sense, promoting physical activity during childhood and adolescence is an insightful strategy for good health for young people.

Among the known benefits, a good bone health seems to be directly related to involvement with vigorous physical activity in childhood[2,3], once moderate to vigorous physical activity (MVPA) plays a recognized osteogenic effect on bone[4,5]. However, the huge increase in sedentary time among children[6] especially in Brazil[7] leads to consider the effects of this behavior in studies about PA and bone health.

A review study by Koedijk et al.[8] suggest that sedentary behavior is associated with adolescent's lower extremity bone outcomes, such as the bone mineral density of the femoral neck. Two high-quality articles include in this review indicated that objectively measured total sedentary time was negatively associated with bone outcomes. The results showed that an additional hour of sedentary time was associated with 0.006 g/cm^2 lower femoral neck bone mineral density (BMD) in 11–14-year-old boys and every additional hour of MVPA was associated with 0.02 g/cm^2 increase in femoral neck BMD. The authors further suggest that one hour less on sedentary time per day has the same effect on femoral neck BMD as 18 minutes of MVPA in boys.

This relationship clear when considering obese children. Despite of obesity is traditionally viewed as favorable to bone health because of the positive effect of mechanical body weight´s loading on bone formation, epidemiological[9] and animal[10] studies strongly support that fat accumulation is unfavorable to bone mass. Additionally, a recent review study[11] showed that longitudinal results remain inconclusive once only 50% of the included studies reported a positive effect of a structured intervention program on bone health. Results of the meta-analysis highlighted that structured interventions did not influence bone markers, even considering beneficial effects on general health of obese youth.

Though the benefits of physical activity on bone health are recognized in normal-weight children, the studies realized with obesity children should take into account potential confounders such as serum levels of vitamin D, or lean and fat mass. Thus, this was a twofold aim study: (1) to examine changes in body composition variables (fat mass; lean mass; body mass index (BMI)); bone tissue variables (BMD; bone area (BA) and bone mass (BM)) and physical activity intensities along with sedentary time, and (2) to explore whether changes in time spent in different physical activity intensities and in sedentary time are associated with changes in bone outcomes after eight months of a school-based intervention program.

Methods

The «ACORDA Project» (i.e. Obese Children and Adolescent Involved in Physical Activity and Diet Program) is an interdisciplinary school-based intervention study, focused on overweight and obese youth, which, aimed to change behaviors by providing easy access to physical activity. The ACORDA´s purpose is to change obesity-related behaviors in youth by providing easy access to supervised PA and associated nourishment counselling and clinical supervision.

The voluntary non-representative sample of this study comes from 6 public schools of Porto, Portugal. An invitation letter was sent to all parents, acknowledging the mission of the project and inviting them to participate in a meeting where they would be informed about the aims, contents and evaluation protocols. All volunteers were screened for eligibility criteria. Participants under regular medication or with diabetes mellitus, endocrine disorders, inflammatory or infectious diseases don't meet the inclusion criteria. Further details may be seen elsewhere[12].

A total of 82 students (10 years old on average) of both genders recruited in Porto public schools were eligible and volunteered to participate in the study, although 29 did not complete all the evaluation protocol. Therefore, over a period of 8 months, 53 students were assigned, and: (1) did all the testing procedures at time point 0 (baseline – TP0) and time point 1 (post-intervention – TP1); (2) were not attending any other formal sports or physical activity program. All the participants were stimulated to modify their lifestyle habits and to engage in regular physical exercise classes.

The planning program converged in three hours of mandatory Physical Education formal classes and two hours of after-school sessions (1h each session), resulting in a total of five hours per week, from October to June 2012/2013. The project´s coordinators previously planned the exercise sessions for each class and each after-school session. Two graduates in Sport Sciences, under the guidance of two researchers, taught the classes, ensuring that the type and variety of exercises would be performed according to previously planned, and equally applied to all schools. Physical exercise sessions included 15 minutes for warm-up with aerobic endurance and flexibility, 30 minutes of working circuit for aerobics, strength training, coordination and balance (with balls, bows, strings and callisthenic exercises), 10 minutes of games to promote the enjoyment and five minutes of stretching. All activities were done in indoor schools sports facilities. Exercises and games were progressively intensified as individually tolerated, according to their heart rate and subjective perception of effort. Training intensity and compliance between individuals were defined to induce heart rate (HR) higher than 70% of each child's HRmax. To ensure this, 10 randomly selected children wore a portable HR monitor during sessions (Polar Team2 Pro, Polar, Finland). Attendance was in average of 85%.

The Regional Education Board approved the study protocol, and students, parents and schools agreed to participate. The nature, benefits, and risks of the study were explained to the volunteers, and a parent's written informed consent was obtained before the study, consistent with the Helsinki Declaration. The experimental protocol was approved by the Review Committee of the Scientific Board of the Faculty of Sport, University of Porto, as well as by the Foundation of Science and Technology under the process: PTDC/DTP-DES/0393/2012. The project staff, according to the approved study protocol, did all the measurements.

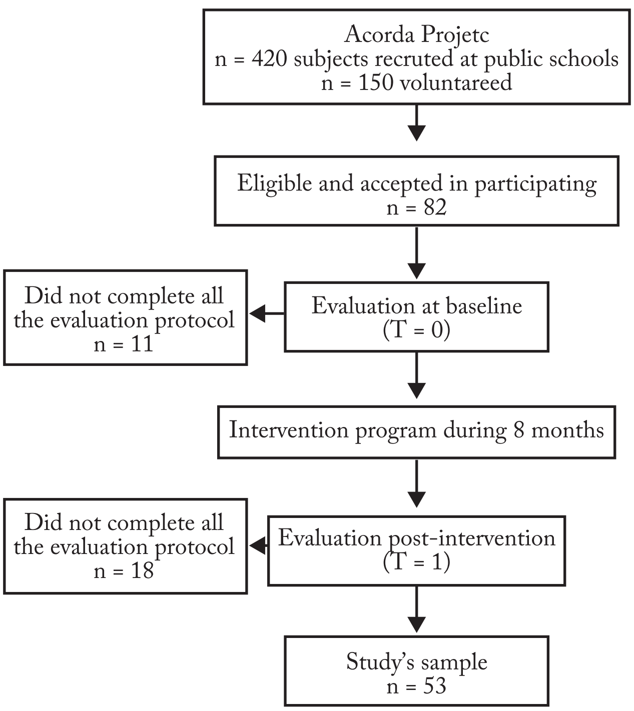

Figure 1 – Study flow diagram of schools and participants through the 8-months intervention. Porto, Portugal, 2013 (n = 53).

This information was recorded in a cadastral record, along with the subject's name, gender and age. Height and weight were measured with participants wearing only shorts and t-shirts. Height was measured using a Holtainstadiometer (Holtain Ltd., Crymmych, UK) and recorded in centimeters to the nearest millimeter. Weight was measured to the nearest 0.1 kg with the scale Tanita MC 180 MA. BMI was calculated by the ratio between weight and squared height (kg/m^2). Body mass index categories were set using international recommended age-sex cut points[13].

Maturational stage was determined on an individual basis during physical examination. Each participant self-assessed his/her own stages of secondary sex characteristics: stage of breast development in females and pubic hair in males[14]. A previous study showed a high correlation (r = 0.73) between ratings on two occasions (three days interval) in a sub-sample of 50 selected subjects. Concordance between self-assessments of sexual maturity status and physician assessment ranged from 63% for girls and 89% for boys[15]. This information was used as a co-variable in the statistical procedures.

Whole body Dual-energy X-ray Absorptiometry (DXA) was performed using a Hologic Explorer configured with a software version 12.1 (Hologic, Bedford, MA). Measurements were analyzed using Hologic APEX 3.1 software (Hologic) according to standard procedures set in the user's guide for the DXA instrument, and BM, BA, and BMD z-score (primary outcome variables). Body lean mass (BLM) and body fat mass (BFM) were also reported (secondary outcome variables). The in-vivo coefficient of variation (CV) was 0.5%.

In order to minimize DXA analysis error in a repeated measurements approach, one operator analyzed all scans (baseline and follow-up) in a short period of time, so that consistency of procedures were optimized, and few changes were done from the default scan[16].

After an overnight fast, blood was obtained by venipuncture in EDTA containing tubes and processed within 2 hours of collection. Fasting serum samples were analyzed for 25 (OH) D (vitD) by chemiluminescent assay. The same control and reagent lots were used for the analysis of the samples, and all of the samples, in duplicate, from a participant were run in the same assay. The inter-assay CVs for the low and high controls were 8% and 6%, respectively, and the intra-assay CVs for the low and high controls were 5% and 3%, respectively.

Physical activity was objectively assessed by accelerometers (wGT3x, Actigraph, Florida) during seven consecutive days. Data was stored in raw mode in samplings of 30Hz. With a specific software (ActiLife, version 6.9, Actigraph, Florida), data was reduced into one-minute periods (epochs), organized into daily physical activity and analyzed after data collection. Wear and nonwear time were determined according to established algorithms[17]. Time periods with at least 10 consecutive minutes of zero counts recorded were excluded from analysis assuming that the monitor was not worn. A minimum recording of 8-hours/day (480-minutes/day) was the criteria to accept daily physical activity data as valid. Individual's data were only accepted for analysis if at least three-week days and one weekend day were successfully assessed. The main outcomes of reduced accelerometer data were: total physical activity (total Physical Activity (counts/min/day)), time in sedentary behavior (sedentary time (min/day)), light physical activity (Low Physical Activity (min/day)), and moderate to vigorous physical activity (MVPA (min/day)).

International recommendations[18,19] cut-points for youths were used to determine time spent in PA of different intensities. The following counts intervals were considered: 0-100 for sedentary time, 101-2295 for low physical activity, and ≥ 2296-4011 for MVPA[18].

Descriptive data for continuous variables are presented as mean, ± standard deviation for adjusted analyses. At baseline, preliminary Independent Student's T-test was carried out to analyze differences between boys and girls in the entire sample, for all the studied variables, and no statistically significant differences were seen ($p < 0.05$). Paired Student's T-test was carried out to analyze differences between TP0 and TP1, and it was shown statistically significant differences between the two times for some variables.

For descriptive purposes, relative changes (%Δ) were calculated as ((TP1-TP0)/TP0)*100, and partial correlations between %Δ of the different bone variables and the other measured variables were analyzed, after adjustments for sex, age at post-test (T1), maturational status, vitD at baseline, and %Δheight. The main results for General Linear Models (GLM) - Repeated Measures Analysis of Covariance - were based in the analyses of BMD z-scores, according to the American Academy of Pediatrics Association guidance[20].

GLM was carried out with adjustments for potential confounders: sex, age, maturational status, %ΔvitD, %Δheight, %Δlean mass, and %Δfat mass (model 1). If this analysis was significant, it was considered to be indicative of a significant treatment (intervention) effect. Considering differences between the two time points, adjustments for sedentary time relative change (%ΔST) (model 2), and %ΔMVPA (model 3) were also analyzed. All analyses were performed using the SPSS 21.0 (SPSS Inc., Chicago, IL) for Mac OSX and significance level was set at 5%.

Results

Table 1 shows descriptive data of the entire sample. At baseline, we ran t-test between gender and no statistically significant differences were found (data not showed). Pairwise comparisons indicated statistically significant increase between T0 and T1 for height lean mass, BA, BM ($p < 0.01$), as well as for BMD z-score, and MVPA ($p < 0.05$), while statistically significant decrease were found for weight, ($p < 0.01$) and sedentary time ($p < 0.05$).

Partial correlations between relative changes in bone variables, body composition and physical activity levels are shown in Table 2. Correlations were adjusted for sex, age, maturational status, vitD at baseline, and

Table 1 - Descriptive analysis of the measured variables in overweight/obese children at the two time points. Porto, Portugal, 2013 (n = 53).

	Means ± SD T0	Means ± SD T1	Paired Differences Mean	95% CI for Mean Difference	*P* -value	Δ (%)
Age (year)	10.6 ± 3.5	10.5 ± 3.5	-0.02	(-0.09; 0.05)	0.569	-0.1 ± 2.9
Height (cm)	139.9 ± 14.8	142.7 ± 14.2	2.71	(2.12; 3.29)	0.000**	2.0 ± 1.6
Weight (kg)	46.5 ± 20.9	47.6 ± 20.9	1.11	(0.45; 1.78)	0.001*	2.7 ± 4.7
BMI (kg.m^{-2})	22.6 ± 5.7	22.3 ± 5.8	-0.27	(-0.58; 0.04)	0.083	-1.3 ± 4.8
FM (kg)	17.7 ± 10.6	17.9 ± 10.1	0.19	(-0.39; 0.78)	0.509	2.5 ± 10.6
LM (kg)	26.2 ± 11.2	27.6 ± 10.9	1.43	(0.68; 2.18)	0.000**	36.6 ± 23.4
BA (m^2)	13.8 ± 3.2	14.2 ± 3.2	0.41	(0.27; 0.55)	0.000**	3.1 ± 4.1
BM (kg)	1.19 ± 0.50	1.25 ± 0.51	0.06	(0.05; 0.08)	0.000**	5.6 ± 6.4
BMD z-score	0.24 ± .84	0.44 ± .87	0.20	(-0.33; -0.07)	0.007*	0.8 ± 3.2
VitD	23.0 ± 6.3	21.3 ± 4.4	-1.65	(-3.82; 0.53)	0.135	3.1 ± 5.1
ST (min/day)	1024.6 ± 85.4	985.5 ± 85.7	-39.09	(-63.40; -14.78)	0.002*	-3.5 ± 8.2
LPA (min/day)	356.5 ± 138.2	362.8 ± 76.0	6.23	(-41.88; 54.35)	0.794	8.0 ± 24.4
MVPA (min/day)	48.1 ± 23.7	58.0 ± 28.5	9.92	(1.72; 18.13)	0.019*	33.4 ± 64.8

BMI = body mass index; FM = fat mass; LM = lean mass; BA = bone area; BM = bone mass; BMD z-score = bone mineral density z-score; VitD = vitamin D; ST = sedentary time; LPA = low physical activity; MVPA = moderate to vigorous physical activity; Differences (* p < 0,05; ** p < 0,01) between the two time points (T0 and T1); SD = standard deviation.

%Δheight. Positive changes (increased levels) of MVPA were positive and significantly correlated with increased levels of BA, BM and BMD z-score. In addition, BMD z-score was inverse and significantly correlated with decreased values of sedentary time and %ΔFM. Any other statistically significant differences were found.

The results for GLM (Table 3) showed a significant effect of the exposure in %ΔBMD z-score (F = 2.252; η^2 = 0.132). After adjustments for relative changes in sedentary time and MVPA, no significant effect was observed.

Discussion

This study explored whether changes in physical activity intensities as well as sedentary time are related to changes in bone outcomes in obese/overweight children and adolescents after 8 months of a school-based interdisciplinary intervention program. To the best of our knowledge, this is one of the few studies presenting associations between variables of bone mass with sedentary time and physical activity intensities objectively measured in a group of overweight/obese youngsters.

Our study design aimed to assess the effect of a school-based physical activity program on a given population (overweight/obese youngsters), performing "pre-post" intervention measures. Nonetheless, it has the strength of temporality, which might suggest that the outcome is impacted by the intervention[21]. Noteworthy, was the fact that our data showed a significant overall effect of the intervention on %ΔBMD z-score, that after adjustments for changes in sedentary time and MVPA, no significant effect was observed. These findings highlight that variations in sedentary time and in MVPA play an important role in BMD in those children and adolescents involved in the interdisciplinary program.

Indeed, our data agreed with previous studies showing that in Spanish boys, self-reported screen-based activities were associated with an increased risk for low whole body BM[22]. Other study has shown that 8 months of physical activity program lead towards a significant gain of bone mineral content in proximal femur and in the intertrochanteric region in children aged 8-10 year-olds[23]. In addition, and reinforcing the role of physical activity, a randomized control trial study in obese children showed higher increase in bone mineral content in trained group compared to the diet-alone[24]. Further, increased bone mass during childhood and adolescence (obese or non-obese) has been associated to the frequency, intensity and type of physical activity[25], especially in Physical Education[26].

The study by Ivuškāns et al.[27] also investigated the influence of the change in physical activity - evaluated by accelerometer - on bone variables in peripubertal boys (BMI average = 19.77). As in the present study, the main results described by authors were the ability of MVPA

Table 2 – Partial correlations between relative changes[a] of the measured variables in the overweight/obese children. Porto, Portugal, 2013. (n = 53).

Relative changes after intervention	%ΔBA		%ΔBM		%ΔBMD z-score	
	r	p-value	r	p-value	r	p-value
%ΔFM	0.269	0.353	0.220	0.450	0.546	0.035*
%ΔLM	-0.043	0.884	-0.125	0.669	0.361	0.204
%ΔST	-0.493	0.073	-0.322	0.261	-0.594	0.010*
%ΔLPA	0.216	0.459	-0.075	0.799	-0.336	0.239
%ΔMVPA	0.669	0.009*	0.657	0.011*	0.596	0.039*

a = Adjusted for sex, age, maturational status, vitD at baseline, %Δ weight and %Δ height; %ΔFM = relative change fat mass; %ΔLM = relative change lean mass; %ΔST = relative change sedentary; %ΔLPA = relative change low physical activity; %ΔMVPA = relative change moderate to vigorous physical activity; %ΔBA = relative change bone area; %ΔBM = relative change bone mass; %ΔBMD z-score = relative change bone mineral density z-score; * p < 0,05.

Table 3 – Generalized Linear Models analysis for the effect of the intervention in % Δ bone mineral density z-score in overweight/obese children. Porto, Portugal, 2013 (n = 53).

Relative changes in BMD	TP0		TP1				
	Mean	SE	Mean	SE	Time effect F	p-value	Partial Eta^2
%Δ BMD z-score Model 1[a]	0.128	0.142	0.188	0.147	2.252	0.000**	0.132
%Δ BMD z-score Model 2 (%ΔST)	0.238	0.144	0.292	0.136	1.173	0.296	0.073
%Δ BMD z-score Model 3 (%ΔMVPA)	0.319	0.185	0.344	0.156	0.304	0.605	0.057

a = Adjusted for sex, age, maturational status, %Δ vitD, %Δ height, %Δ lean mass, and %Δ fat mass; %ΔBMD z-score = relative change bone mineral density z-score; %ΔST = relative change sedentary time; %ΔMVPA = relative change moderate to vigorous physical activity.** p < 0.01.

and sedentary time to influence the modification of bone mass in one year. Another common point is that light physical activity was not associated with any bone variable at cross-sectional and longitudinal analyzes.

Other studies also demonstrate light physical activity as absent in relations with bone variables[11,27]. However, overweight/obese children and adolescents are more predisposed to light physical activity and sedentary activities and these variables should be considered in studies with this population. Because light physical activity is an important variable of the children's general physical activity behavior and sedentary time influences a reduction or stagnation of bone mass development.

The ability of physical activity to stimulate bone remodeling is determined by the nature and magnitude of the load, the rate at which the load is applied, and the duration of the loading session. During childhood, bouts of high-impact activities augment bone mass accrual and enhance bone´s structural characteristics[28]. So, the increased levels of MVPA levels achieved at T1 (post-intervention) may have positively influenced the better bone profile observed in our obese/overweight sample.

The osteogenic effect of high-level physical exercises, that is, the MVPA characterized by high volume and intensity, has already been reported in other populations[29]. However, when thinking about school-based interventions, the intensity and volume of activities should be considered with caution. However, this is still one of the best intervention strategies for the young population in general. Besides having applicability, it demonstrates relevant results in bone health[26].

Despite the intervention had last 8 months, and no follow-up measures has been taken, we do believe that variation in MVPA levels lead towards a better BM in these overweight/obese children. Indeed, a review suggested three possible mechanisms to explain the deleterious effect of obesity on bone metabolism, as such (1) obesity status, by increasing adipogenesis, may decrease osteoblastogenesis because adipocytes and osteoblasts are derived from a common multipotential stem-cell; (2) obesity is associated with chronic inflammation, and proinflammatory cytokines are the main mediators of osteoclast differentiation as well as bone reabsorption is increased in chronic inflammatory disorders, and, (3) a high fat diet may compromise intestinal calcium absorption by insoluble calcium soaps produced from free fatty acids[30]. Though, even without a significant decrease in FM, the positive increase observed in LM may have influenced the bone profile.

Our results refer to a population that presents high chances of development of several diseases throughout the life. Therefore, a strong point of this study is the rigor in the evaluation method of the variables (scientific point), mainly by the use of gold standard evaluations to evaluate physical activity, sedentary time, blood and bone variables. And also, the proposition of an intervention applicable in the school environment (social point), whose effect is beneficial in an important area of the young people health.

Notwithstanding these points, some limitations must be considered. Our longitudinal results cannot be compared to a similar group of Portuguese children due to the absence of a control group. However, the authors used all available techniques to minimize this limitation.

In conclusion, the 8-months interdisciplinary intervention program showed positive correlations between the variation in MVPA and the variations in all the measured bone outcomes. A significant overall effect of the intervention on BMD z-score was observed. After adjustments for changes in ST and MVPA, no significant effect was observed. These findings highlight that in those children and adolescents involved in the program, variations in ST and in MVPA play an important role in BMD.

Conflict of interest

The authors declare no conflict of interest.

Authors' contributions

Mello JB, collaborated with the analysis, interpretation and discussion of the results, writing of the text and approval of the final version. Lemos LFGBP, collaborated with the data collection, execution of the intervention. Aires LM, collaborated with the design of the research project, data collection, execution of the intervention. Silva G, collaborated with the design of the research project, data collection, execution of the intervention. Tassitano RM, collaborated with the writing of the text. Mota JA, collaborated with the design of the research project, supervision of the writing of the text and approval of the final version. Gaya AR, collaborated with the analysis, interpretation and discussion of the results, wording of the text and approval of the final version. Martins CML, collaborated with the design of the research project, data collection, execution of the intervention, analysis of the data, supervision of the writing of the text and approval of the final version.

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