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Original Article

Association between knee alignment, body mass index and physical fitness variables among students: a cross-sectional study

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ABSTRACT

Objective: To assess the association between malalignment of the knees (genu valgum) and variables of physical fitness among schoolchildren. *Methods*: We analyzed data collected between the years 2000 to 2009. The sample comprised 1,141 schoolchildren of both sexes aged 06 to 18 years. To participate in the research, the students must meet the following criteria: age between 6 and 18 years and a full assessment of physical fitness, including measurement of genu valgus in at least one of the semester assessments. Postural evaluation (valgus) was determined by the intermalleolar distance, in centimeter. Body Mass Index (BMI) determined through the growth curves of the World Health Organization. Physical fitness variables (strength of upper and lower limbs, agility, speed and flexibility), were taken according to CELAFISCS standardization. *Results*: Among male students it was found a prevalence of 23.2% obese, 44.4% overweight and 32.4% eutrophic. Among females, the values were: 30.9% obese, overweight 39.5% and 20.6% eutrophic. When analyzing the prevalence of valgus according to the BMI classifications it was, found a significant positive association in both sexes. Associa-

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tion was found between genu valgum and upper limbs strength only in crude analysis. The other variables, agility, speed and flexibility were not associated even when the analysis was adjusted. *Conclusion*: there was a positive association between malalignment of the knees, body mass index and physical fitness among schoolchildren.

Introduction

Data from around the world have demonstrated increasing prevalence of obesity, not only among the adult population but also among young adults and adolescents.[1] This increase is strongly associated with two main factors, among other causes: low levels of physical activity and increased intake of highly calorific foods.[2,3]

Regular practicing of physical activity may positively influence the levels of physical fitness.[4] However, biomechanical and/or postural abnormalities such as knee misalignment seem to be one of the possible causes that may limit individuals' engagement in physical activities, given that in addition to the specific local alterations, these may affect other joints and limit the capacity for exercise.[5]

One of the deviations that most affect children and young adults is genu valgum. This knee misalignment is defined as displacement of the knees in relation to the proximal axis of the body, and it is more prevalent among girls. In cases of high degrees of valgus, this may directly influence performance relating to neuromotor variables of physical fitness, such as speed and agility, and also anthropometric variables like body adiposity.[6]

Some hypotheses have suggested that overweight and obese individuals would have greater likelihood of presenting postural deviation (genu valgum).[7,8] On the other hand, other authors have suggested that higher degrees of genu valgum may have implications for maintaining a physically active lifestyle, thereby increasing the chances of presented greater-than-expected weight.[9]

The objective of the present study was to analyze the association between genu valgum, body mass index and physical fitness among students at public schools.

Methods

The present study forms part of the Mixed Longitudinal Growth and Development Project of Ilhabela, which has been developed by CELAFISCS since 1978. In this, the impact of the growth and development process on physical fitness variables among children in the municipality of Ilhabela (São Paulo, Brazil) is studied.

This project makes semestral assessments, always in April and October, and includes anthropometric, metabolic, neuromotor, nutritional and, more recently, physical activity level measurements. To make up the sample for the present study, a database of more than 3,500 children and adolescents of both sexes who participated in evaluations between 2000 and 2009 was analyzed. Among these subjects, 1,141 met the inclusion criteria used, i.e. they were between 6 and 18 years of age and a complete assessment of physical fitness, including measurements of genu valgum, were available. This project was approved by the Ethics Committee of the Universidade Federal de São Paulo, under protocol n# 0056/10.

Knee misalignment (genu valgum) was assessed with the students in an upright standing position, with observation in the posteroanterior direction, using a rule marked out in centimeters (cm). The intermalleolar distance was measured in cm as recommended by Heath and Staheli.[10]

Body mass measurements were obtained using a digital scale with precision of 100 grams, with the individual wearing as little clothing as possible. Height was measured using a stadiometer, in cm, and was calculated as the average of three measurements. To calculate the body mass index (BMI), the above two measurements were used and the subjects were classified as eutrophic, overweight or obese, in accordance with the criteria proposed by the World Health Organization.[11]

Lower-limb strength was measured by means of the vertical impulse test, without aid from the upper limbs (cm), and three attempts were made. To measure upper-limb strength, the hand grip test was used with a dynamometer (kg). The variable of agility was measured using the "shuttle run" test (seconds), with two attempts. For the speed test, running over a distance of 50 meters (seconds) was used, with a single attempt. Flexibility was estimated (cm) using the "sit and reach" test.[12]

All the measurements and tests followed the standardization of CELAFISCS[13] and took into consideration the best result from each test. The reproducibility and objectivity values for each measurement made between the years ranged from 0.96 to 0.99 for body mass, 0.97 to 0.99 for height, 0.51 to 0.97 for upper-limb strength, 0.62 to 0.92 for lower-limb strength, 0.58 to 0.89 for agility, 0.61 to 0.91 for flexibility and 0.58 to 0.92 for speed, respectively.

Statistical analysis

The descriptive analyses were detailed by means of absolute numbers and proportions for categorical data. Bivariate analyses between the physical activity level and independent variables were conducted using chi-square tests for heterogeneity (categorical variables) and for linear trend (ordinal variables). To analyze the physical fitness variables, increasing terciles were created because classification criteria existed for the variables used in the present study.

Analyses adjusted for possible confounding factors were performed by means of Poisson regression with robust adjustment of variance.[14] The variables were selected by means of the "bottom-down" method.[15] Variables with p values < 0.20 were retained in the final analysis model. The significance level used was $p < 0.05$. All the analyses were conducted by means of the Stata version 10.0 statistical package.

Results

The data for the present study was supplied by 1141 individuals who fulfilled the inclusion criteria. The mean age of the sample was 11.16 ± 2.65 years (boys 11.25 ± 2.74 and girls 11.09 ± 2.57). The mean BMI was 18.17 ± 3.27 kg/m^2 (boys 17.92 ± 3.19 kg/m^2 and girls 18.37 ± 3.31 kg/m^2).

After adjusting for age and sex, the prevalence of obesity among the girls was 45% (95% CI: 1.21 – 1.74) greater than the prevalence of eutrophic individuals, while the prevalence among the boys was 34% greater (95% CI: 1.08 – 1.66) (Table 1).

Table 1 - Multivariate analysis on the association between genu valgum and body mass index, among students in the municipality of Ilhabela, stratified by sex.

Variables	Crude PR (95% CI)	p	Ajusted PR** (95% CI)	p
Boys BMI		< 0.002 *		0.007 *
Eutrophic	1.0		1.0	
Overweight	1.17 (0.95 – 1.43)		1.15 (0.94 – 1.45)	
Obese	1.40 (1.13 – 1.17)		1.34 (1.08 – 1.66)	
Girls BMI		< 0.001 *		< 0.001 *
Eutrophic	1.0		1.0	
Overweight	1.22 (1.02 – 1.47)		1.21 (1.01 – 1.46)	
Obese	1.48 (1.24 – 1.77)		1.45 (1.21 – 1.74)	

* Wald test for heterogeneity; **adjusted for age and sex.

Table 2 presents a description of the sample for all the independent variables and their associations with genu valgum. The prevalence of genu valgum encountered was 56.6% (95% CI: 53.7 – 59.4). Among females, the prevalence was 59.2% and among males, 53.6%. Among the girls, 20.6% were classified as eutrophic, 39.5% as overweight and 30.9% as obese. Among the boys, the values were 32.4% eutrophic, 44.4% overweight and 23.2% obese.

Analysis on associations with the degree of genu valgum showed that individuals with better performance in the lower-limb strength test presented lower prevalence of knee misalignment ($p \leq 0.001$).

Table 3 shows the crude and adjusted analyses on the association between genu valgum and the independent variables. After adjustment for confounding variables, genu valgum was seen to be associated with age and BMI, with prevalence in the obese group that was 40% (95% CI: 1.22 -1.60) greater than among the eutrophic individuals.

Table 2 - Knee alignment according to the independent variables of students at public schools in the municipality of Ilhabela, São Paulo.

Variables	N (%)	Genu valgum (%)	P
Age			0.007 *
6 to 10	425 (37.2)	262 (40.6)	
11 to 14	577 (50.6)	317 (49.1)	
15 to 18	139 (12.2)	139 (12.2)	
BMI			<0.001 *
Normal	349 (30.9)	164 (25.59)	
Overweight	473 (41.8)	266 (41.50)	
Obese	309 (27.3)	211 (32.9)	
Sex			0.05
Female	613 (53.7)	363 (56.2)	
Male	528 (46.3)	283 (43.8)	
Lower-limb strength			<0.001
1st tercile	376 (33.8)	231 (37.0)	
2nd tercile	408 (36.7)	236 (37.8)	
3rd tercile	327 (29.4)	158 (25.3)	
Upper-limb strength			0.08
1st tercile	382 (33.9)	226 (35.5)	
2nd tercile	371 (33.01)	218 (34.2)	
3rd tercile	371 (33.01)	193 (33)	
Flexibility			0.85
1st tercile	375 (33.4)	213 (35)	
2nd tercile	422 (37.5)	242 (30)	
3rd tercile	327 (29.1)	181 (28.46)	
Agility			0.44
1st tercile	377 (33.9)	209 (33.2)	
2nd tercile	388 (34.9)	230 (36.5)	
3rd tercile	346 (31.1)	191 (30.32)	
Speed			0.12
1st tercile	384 (35.7)	202 (33.5)	
2nd tercile	347 (32.3)	195 (32.3)	
3rd tercile	343 (31.9)	206 (34.2)	

*p < 0.05.

Table 3 - Multivariate analysis on the association between genu valgum and the independent variables of students in the municipality of Ilhabela, São Paulo.

Variables	Crude PR (95% CI)	P	Ajusted (95% CI)	P
Age***		<0.001 *		0.007 *
6 to 10	1.0		1.0	
11 to 14	0.89 (0.80-0.99)		0.89 (0.80-0.99)	
15 to 17	0.78 (0.65-0.94)		0.78 (0.65-095)	
BMI**		<0.001 *		<0.001 *
Eutrophic	1.0		1.0	
Overweight	1.20 (1.04-1.37)		1.18 (1.03-1.36)	
Obese	1.45 (1.27-1.66)		1.40 (1.22-1.60)	
Sex ****		0.06*		0.06*
Female	1.0		1.0	
Male	0.90 (0.81-1.00)		0.91 (0.82-1.00)	
Lower-limb strength**		0.09*		0.07*
1st tercile	1.0		1.0	
2nd tercile	1.00 (0.85-1.17)		1.03 (0.87-1.21)	
3rd tercile	0.84 (0.76-0.94)		0.90 (0.79-1.01)	
Upper-limb strength**		0.05*		0.70*
1st tercile	1.0		1.0	
2nd tercile	0.99 (0.88-1.12)		1.08 (0.95-1.24)	
3rd tercile	0.88 (0.77-0.99)		1.03 (0.87-1.23)	
Speed**		0.04*		0.84*
1st tercile	1,0		1,0	
2nd tercile	1.07 (0.93-1.22)		0.98 (0.86-1.15)	
3rd tercile	1.14 (1.01-1.30)		1.01 (0.87-1.18)	

* Wald test for heterogeneity; ** adjusted for age and sex;
*** adjusted for sex; **** adjusted for age. **** ajustado para idade.

An association was found between genu valgum and upper-limb strength was only found in the crude analysis. The other variables (agility, speed, lower-limb strength and flexibility) did not present any association even when the analysis was adjusted (Table 3).

Fig. 1 presents a correlation between the degree of genu valgum (percentiles) and BMI. The proportion of the individuals classified in the percentile ≥ 75 was greatest among the obese subjects ($p < 0.001$). The lowest BMI (eutrophic individuals) presented a significant association with lower degree of genu valgum, i.e. the greater the degree of valgus was, the greater the obesity was; and reciprocally, the lower the degree of valgus was, the lower the degree of adiposity was.

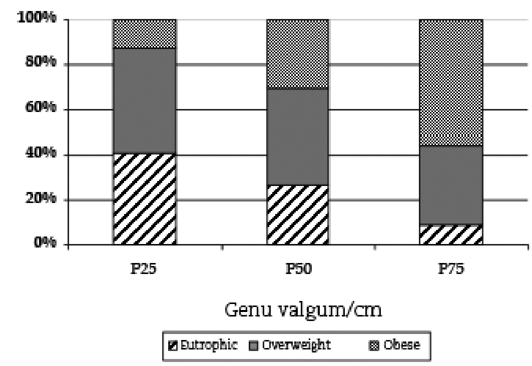

Fig.1 - Association between degree of genu valgum and body mass index among students in Ilhabela, SP.

Discussion

The Longitudinal Growth, Development and Physical Fitness Project among students in Ilhabela has provided an important original line of approach on posture that has sought to correlate postural deviation with motor performance and anthropometric, neuromotor, metabolic and physical activity characteristics. The results found in the present study showed that there was a significant association between genu valgum and physical fitness variables among students of both sexes in Ilhabela. In addition to the present study, other authors[9,16,17] have also undertaken research projects among students in Ilhabela, showing correlations between physical fitness and the intermalleolar and intercondylar distances among students in Ilhabela.

A study that analyzed 274 students of both sexes aged 7 to 18 years found a significant association between the degrees of genu valgum and the physical fitness variables (body mass, agility and speed).[9] In the same study, the prevalence of genu valgum found was 68.6%, and the authors observed that the young people who presented greater degrees of valgus had deficits of 10% in speed tests.

Martinelli et al.[18] found that the prevalence of genu valgum was 87% among overweight children of both sexes aged 5 to 9 years. These authors did not find any statistical difference between the sexes. According to Gomes et al.,[19] the prevalence of genu valgum varied over the years, with a relationship with different developmental stages.

According to Cardoso et al.,[5] Gomes et al.,[19] MacMahon et al.[20] and Arazi et al.,[21] in addition to knee alignment variations (valgus, varus or neutral)with age among normal children, the prevalence of genu valgum is greater during infancy, especially between the ages of 2 to 6 years. These authors stated that high degrees of genu valgum might have implications for maintaining a physically active lifestyle among children and adolescents. Through this, the chances that such children would present greater-than-expected weight would be higher. This hypothesis was supported by the findings from the present study.

Joao et al.[22] measured the angling of the knees using a goniometer and the distance between the malleoli using a measuring tape, in a study on 79 children aged 7 to 10 years. These authors observed that the group of obese subjects presented greater prevalence of valgus knee in the two methods of evaluation.

A literature review study demonstrated that valgus and varus knee deformities may give rise to lower-limb dysfunction that has important consequences for activities of daily living, such as walking, sitting down and getting up, and going up and down stairs.[23,24]

It is extremely important to emphasize that the results from the present study and from other studies conducted so far[9,16,24,25] only show a relationship between the intermalleolar and intercondylar distances and the obesity and physical fitness variables in children and adolescents.

According to some authors,[23,26] obese adolescents have been shown to present localized orthopedic alterations, particularly in the lower limbs, such as genu valgum. Jannini et al.[23] conducted a cross-sectional study among eutrophic and obese adolescents. They concluded that obesity may cause damage to the osteoarticular system at the beginning of adolescence.

According to Calvete,[27] obesity causes mechanical overload on the locomotor apparatus and postural misalignment with anteriorization of the center of mass, thus leading to functional alterations in the lower limbs and increased mechanical need for adaptation to the new corporal regime. Yaniv et al.[28] conducted a study among young athletes and found that there were greater postural alterations among older athletes than among younger ones, which may have indicated that the occurrences of changes to the alignment of the lower limbs resulted from sports practice. However, these authors made it clear that further studies using different methods would be needed in order to obtain a broader view regarding the causes of axial deformity.

According to Matsudo[6] and Garcia et al.,[9] genu valgum was more prevalent among girls, which could be in physiologically lighter cases, but in cases of greater intensity and during adolescence there would be greater implications regarding anthropometric and neuromotor fitness, and particularly in relation to adiposity and running for 50 m.

We consider that the present study has certain limitations: there was a lack of criteria for classifying genu valgum; this was a cross-sectional cohort study that did not allow a cause-effect relationship to be established; and no control was made for biological maturity and age, which is an important factor given that postural deviations of the lower limbs undergo modifications with the passing of the years.

Conclusion

Within the limitations of a cross-sectional study, the present findings confirm the hypothesis of a positive association between knee misalignment, body mass index and physical fitness among students. Further studies with appropriate designs that might show a possible cause-effect relationship between the variables analyzed in the present study are needed.

Conflicts of interest

The authors declare that there was no conflict of interests in conducting this study.

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