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Postural disorders produced by school furniture on a population of a junior high school

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ABSTRACT

In recent years people suffering of backache has significantly increased. This led us to focus our attention on the adequacy of school furniture for the correct development of the adult posture.
The standing posture of 67 students of middle school has been analyzed at the beginning and at the end of two consecutive scholastic years using a stabilometric platform. Starting from the second year, about half of the students were provided with the furniture designed following European standard (UNI EN 1729:2006), while the other half maintained the traditional one. The main purpose of this research has been to verify by means of posturometric analysis the effects on postural parameters of the use of traditional furniture in comparison to the furniture following the UNI EN 1729:2006.
We observed that prolonged sitting at school changes some posturometric variables of schoolchildren. Since no differences has been found between the two groups, the validity of the European standards is questioned.
The present study allowed us to single out four anthropometric parameters that should be considered in order to devise a new model of adjustable furniture. By adjusting every year the furniture of each student, it would be possible to avoid (at least at school) the adoption of wrong postural positions that could be responsible for backache and other common musculoskeletal disorders.

Keywords
Posture • Schoolchildren • School furniture • Posturometric and stabilometric platform • Anthropometric parameters

Introduction

In recent years the number of people suffering backache has significantly increased. At the same time, the mean age of the onset of this condition has decreased considerably, affecting even young children up to 10 years old (Watson et al., 2003; Parcells et al., 1999). Such evidences opened the question about the real causes of a condition that over time could develop in permanent disabilities with the known associated economic and social costs (Harreby et al., 1999). In fact, musculoskeletal disorders such as back pain are among the most common pathologies in the world, predominantly between the age of 30 and 50 years, just when people are more productive (Baharampour et al., 2013).
A factor that is common to all suffering individuals is the adoption of wrong postural habits during lifetime and in particular at the age of 8-10 years (Kapandji, 1996). At this age, young people spend most of their time sitting, whether in the classroom or at home. Therefore we focused on the adequacy of school furniture for the correct development of the adult posture.

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Posture is defined as the position of the body in space, as well as the spatial relation between body parts, both in static and dynamic conditions. Biochemical, neurophysiological, psychological, emotional and even relational factors concur to its maintenance. Postural control is influenced by the activity of many neural structures that regulate muscular tone and contraction (Kandel et al., 2000). Proprioceptive inputs from muscles and joints are fundamental for this complex regulation and even the stomatognathic and the visual system are known to play a part in it (Baldini et al., 2013).

There is a growing interest around the world concerning the health of young people in the school environment, particularly regarding posture (Saarni et al., 2007a, b; Limon et al., 2004; Straker et al., 2002, Knight and Noyes, 1999; Yeats, 1997). Several researchers observed a mismatch between the anthropometric data of schoolchildren and the features of existing desks and chairs (Parcells et al., 1999; Castellucci et al., 2010; Panagiotopoulou et al., 2004). Schools in fact are largely equipped with uncomfortable wooden furniture that is not adjustable according to individual parameters. This could create a number of postural and physiological problems for users. If the seat is too high the feet do not rest on the floor, producing postural instability and a compression on the inferior part of the thigh that leads to a slowing down of blood circulation to that area. Similar problems are induced if the seat is too deep, with the edge of the seat putting pressure on the popliteal space. In each case, individuals will tend to slide forward preventing the back to have the support of the backrest and assuming a slumped posture (Parcells et al., 1999). This can also influence the respiratory function (Lin et al., 2006). On the other hand, if the seat is too low individuals may put their legs under the seat and bend forward losing backrest support, or stretch out their legs losing feet support. A too high desk induces hyperextension of the lumbodorsal column, with the person stretching to reach the table top with its forearms; whereas if the desk is too low individuals again will bend forward resulting in a slumped posture and the hyperflexion of the cervicodorsal column with a flattening of the cervical lordosis that leads to neck tension. In addition, the sitting posture might also affect school performance, and this is not an issue to be taken lightly (Koskelo et al., 2007).

Recently, the European Union has acknowledged this problem and issued a norm that concerns the new standards of postural assessment for school furniture (UNI EN 1729:2006). In particular, these rules establish a series of ergonomically-oriented adjustments in the furniture including: a) backrest leaning; b) standardization of sitting space; c) adjustments of desk and seat height by increasing steps of 5 cm (up to 8); d) position of armrest and backrest (CEN-European Committee for Standardization. UNI EN 1729:2006/2012).

Saarni and coll. (2009) in Finland observed, nevertheless, that even the use of ergonomically designed school workstations does not generally improve the musculoskeletal symptoms in children, contradicting in part some previous findings (Koskelo et al., 2007).

Our purpose was to verify, by means of a posturometric analysis, if the corrections introduced by UNI EN 1729 in the traditional furniture might be sufficient to compensate for the wrong postural positions assumed by children at school. This is especially important in elementary and middle school where the furniture is typically too big for the student. To do this, we compared two populations of schoolchildren using either ordinary or UNI EN 1729:2006 furniture measuring their normal standing posture, at the beginning and at the end of the school period for two successive years, since this is affected by an abnormal sitting posture. The analysis was conducted with the use of a stabilometric force platform that measured their moving center of pressure (COP) during standing posture (Dal Zovo, 2010). This is the first time a similar analysis has been conducted.

Materials and Methods

Lizard® stabilometric and posturometric platform

Stabilometry is a debated issue lacking standardization criteria (Scoppa et al., 2013). Still, it is reliable enough to permit a quantitative assessment of posture compared to observational or self-report methods employed by many researchers (Troussier, 1999; Chung and Wong, 2007; Wingrat and Exner, 2005; Murphy et al., 2002).

The Lizard® platform (Lizard S.r.l., Perugia, Italy) is made up of two emi-board that allow an evaluation of the COP in relation to that of right and left foot. The

two emi-boards are placed on the floor by means of three small feet each one including a load cell. When pressure is applied, a sphere of steel conveys strain to the extensometer in the load cell that incorporates a resistance that changes its electrical capacity with deformation. Since the supply current is well known, it is easy to evaluate the loads applied on each cell by measuring the current changes coming out from it. The signal is then amplified and elaborated by a microprocessor. Samplings are made with a 10 Hz frequency.
The platform software calculates posturometric data on basis of the measurements of the loads on each cell. The ideal weight load is symmetrical: 50 ± 2 % on the right foot and 50 ± 2 % on the left, or 16,6 ± 2 % on every of the three support points of each single foot (head of the first metatarsal bone, head of the fifth metatarsal bone, calcaneus) (Kapandji, 1996). This ideal is taken to be the point (0, 0) of the COP in each subject. However, human standing position is not a static one. The body normally oscillates and the COP moves consequently. The platform software elaborates the positions taken by the COP during time in a 2-dimensional Cartesian coordinate system (Figure 1). The following parameters were considered in our analysis.

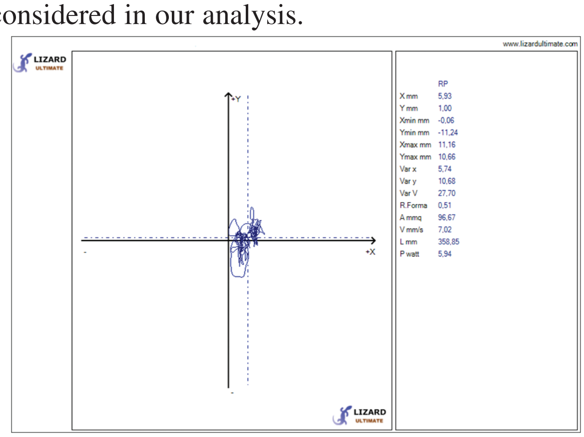

Fig. 1. - Lizard Software.

Baricenter on x axis (BX). It is the average value, measured in mm, of the lateral displacements of the COP. It represents the postural tone symmetry.
Baricenter on y axis (BY). It is the average value in mm of the forward-backward movements of the COP. This data tells us whether the subject puts more weight on his heels or forefeet.
Other data elaborated by the platform software include the average speed of the COP (V), its variance (S2V), and the area covered by it (A). These are all values that express the stability of the postural system and the effectiveness in maintaining the COP near its balance position.

Recording procedure

Subjects had to step barefooted on the platform, aligning each foot with the reference marks depicted on the plates, in order to position them in the most accurate and replicable manner: the second toe and the median part of the heel had to be placed above the central reference line, while the projection of peroneal malleolus had to fall on the lateral line. The distance between the plates was the same for all subjects: the two plates were in contact posteriorly, diverging at an angle of 30°.
They were asked to stand still in upright position with their arms relaxed along the body, looking horizontally at a target on the wall in front of them and keeping the dental arch open. The visual target was at a distance of 3 meters from the platform. The duration of the examination was set at 51.2 s by default.

Subjects and experimental protocol

We analyzed a convenience sample of 67 students between 11 and 12 years of age from a middle school (four classes) in the province of La Spezia (Italy) to evaluate the five posturometric variables described above (BX, BY, A, V, S2V). On each subject we carried out four successive examinations using the Lizard® platform with the following timing: at the beginning of the first scholastic year, at the end of it, at the beginning of the second year and at the end of it. The choice of the sample size is coherent with previous researches in the field (Saarni et al., 2007a; Straker et al., 2002; Saarni et al., 2009). Subjects with major skeletal disorders and muscular impairments were excluded (mild level of scoliosis was not considered such a case).
The purpose of the research was to determine whether there were any changes in the five posturometric variables that could be ascribed to the use of the school furniture by students and whether these changes could be avoided with the adoption of adjustable desks and chairs. Therefore the sample was split in two groups (two classes in each group), with subjects randomly assigned to either group.
In the first year of the study the two groups adopted the standard furniture of the school. We identified

3 types of traditional desks, the height of which was comprised between 67 and 76 cm, and 3 types of chairs, height between 38 and 46 cm, seat depth between 35 and 40 cm. These features were not adjustable.

In the second year, the first group (36 subjects) maintained the classic furniture (ST) while the other group (31 subjects) was provided with the furniture designed following EU prescriptions (FIT). Students in the FIT group were assigned a furniture out of eight classes of dimensions depending on their stature and popliteal height. The characteristics that vary in each class are, among others, desk height (400-820 mm), chair height (210-510 mm), seat depth (270-460 mm) and width (210-410 mm), position of the backrest and of the armrest as established by UNI-EN 1729:2006 (Knight and Noyes, 1999).

All experimental sessions were conducted in the morning before the start of the lessons. Just before each recording phase, it was asked the subjects if they were suffering diseases or injuries that could have affected data comparison.

For the duration of the study we suggested the parents to help their children follow a regular diet and to maintain their usual physical activities outside of school.

Ethics statement

The study was performed in accordance with Declaration of Helsinki principles (1964).

Experimental protocols were approved by CRISAF, Centro di Ricerca Interuniversitario sull'Anatomia Funzionale, Neurofisiologia e Patologia delle posture, statica e dinamica del corpo umano, Institutional Committee of Public Health of Tuscany, University of Siena, Italy.

Written informed consent was obtained from the parents of all students participating in the study.

Data analysis

Descriptive statistics are given as mean ± SD. We performed a mixed factorial ANOVA for the five variables, with time as within-subjects and group as between-subjects factors. Contrasts were used for multiple comparisons. Differences with $p<0.05$ were considered statistically significant. All analyses were performed using statistical packages SPSS software, version 17 (IBM, SPSS Inc., Chicago, IL, USA).

Results

The analysis of BX and BY, the two spatial components of the COP, allowed us to know how far subjects were from the ideal equilibrium position (BX=0, BY=0) and how the use of school furniture modified their standing position. There was a significant effect of time on BX and BY. No interactions between factors were observed. Other parameters expressing the stability of the postural system (V, S2V and A) were not significantly affected.

Center of pressure on the x axis (BX) and left-right displacement

At the beginning of the first year (1st recording), about half of the students had their COP positioned to the right while the other half to the left, referring to the ideal position. That means that they put more weight on the right or on the left foot respectively. The students' COP was subjected to changes between successive recordings (for a quantitative description see Table 1 and Figure 2).

The univariate test shows significant results for the effect of time with a modest effect size, $F(3,180)=3.24$, $p=0.02$, *partial eta squared* (η^2)=0.05, suggesting that BX changes appreciably between the beginning and the end both of the first and the second year.

Tab. 1. - Descriptive statistics for BX in the four trials.

	ST						FIT					
	M	SD	Median	Min	Max	N	M	SD	Median	Min	Max	N
A	-0,1	9,0	0,1	-15,1	24,2	36	1,5	8,7	-1,2	-11,1	28,4	31
B	-1,4	10,4	0,9	-28,9	16,2	36	-2,8	8,9	-1,9	-19,7	17,4	31
C	-2,3	7,4	-2,6	-14,3	13,5	36	-3,2	6,6	-4,3	-14,5	11,2	31
D	0,1	9,6	1,8	-29,5	19,7	36	0,4	10,3	1,8	-33,4	21,8	31

Legend: mean (M), standard deviation (SD), median, minimum and maximum values (Min, Max), sample size (N). **(A)** Beginning of the 1st year; **(B)** end of the 1st year; **(C)** beginning of the 2nd year; **(D)** end of the 2nd year are reported. Values are expressed in mm.

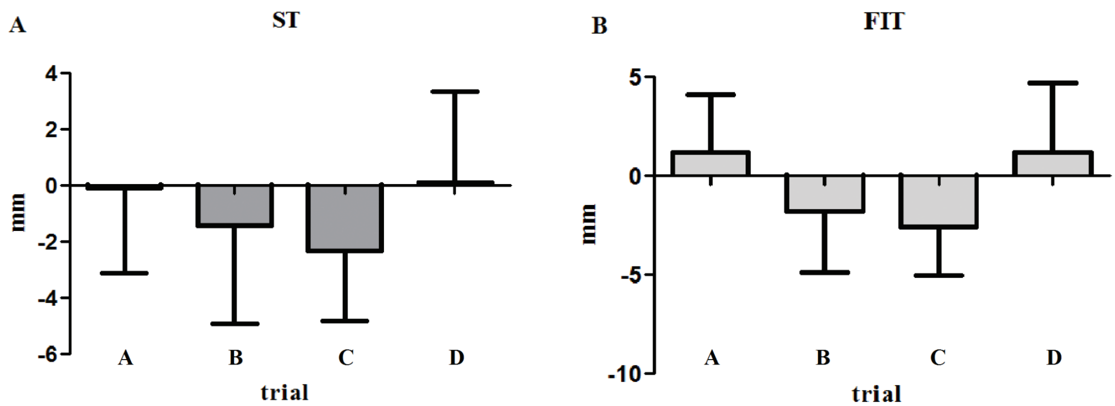

Fig. 2. - BX changes from one recording to the next. The diagram shows mean values ± 95% confidence interval for ST group on the left and FIT group on the right. In abscissa, (A) beginning of the 1st year; (B) End of the 1st year; (C) beginning of the 2nd year; (D) end of the 2nd year are reported. Values are expressed in mm.

However, with the Bonferroni corrections none of the post-hoc comparisons reach statistical significance.

Center of pressure on the y axis (BY) and forward-backward displacement

At the beginning of the first year (1st recording), for most students the COP on y axis (forward-backward) was positioned backward with respect to the point 0 (Figure 3A-B). This means that students put more weight on their heel bones while standing. Figure 3C-H shows the displacement of BY from one recording to the next. There was a clear difference in the displacements for each measurement of BY (for a quantitative description see Table 2 and Figure 4).

The univariate test shows very significant results for the effects of time, $F(3, 180)=16.55$, $p<0.001$, $\eta^2=0.22$. In support of this, the within-subjects contrasts indicated there was a significant cubic trend, $F(1, 60)=43.80$, $p<0.001$, $\eta^2=0.42$. Results for post-hoc comparisons between recordings are given in the following: for the ST group, 1st vs 2nd and 2nd vs 3rd ($p<0.001$), 3rd vs 4th ($p<0.05$); for the FIT group, 1st vs 2nd ($p<0.01$), 2nd vs 3rd (not significant), 3rd vs 4th ($p<0.05$). Importantly, no statistically significant differences were found between the two groups ($\eta^2=0.05$ for group effect; $\eta^2=0.03$ for time x group effect). Thus, it appears that the antero-posterior dimension of COP shifted in opposite directions during successive years independently of the furniture adopted. However, given the very modest effect size we cannot conclude that the two kind of furniture were not different relative to BY modifications. To put it another way, our results failed to acknowledge the UNI EN 1729:2006 furniture a clear vantage in this respect.

Discussion

Children spend many hours in the school environment and the use of school furniture has been indicated as one of the principal cause of back and neck pain (Watson et al., 2003; Parcells et al., 1999; Harreby et al., 1999). To evaluate postural changes after two years of scholastic activity, an

Tab. 2. - Descriptive statistics for BY in the four trials.

	ST						FIT					
	M	SD	Median	Min	Max	N	M	SD	Median	Min	Max	N
A	-19,7	13,4	-17,4	-44,2	8,5	36	-14,5	15,0	-14,3	-34,7	20,3	31
B	-6,6	12,7	-6,2	-31,5	22,1	36	-6,5	13,0	-5,9	-27,5	26,2	31
C	-16,7	14,1	-18,1	-45,5	18,3	36	-12,2	12,3	-11,0	-35,7	19,1	31
D	-10,8	13,7	-8,7	-38,8	16,5	36	-5,5	13,5	-10,1	-25,1	30,9	31

Legend: mean (M), standard deviation (SD), median, minimum and maximum values (Min, Max), sample size (N). **(A)** Beginning of the 1st year; **(B)** end of the 1st year; **(C)** beginning of the 2nd year; **(D)** end of the 2nd year are reported. Values are expressed in mm.

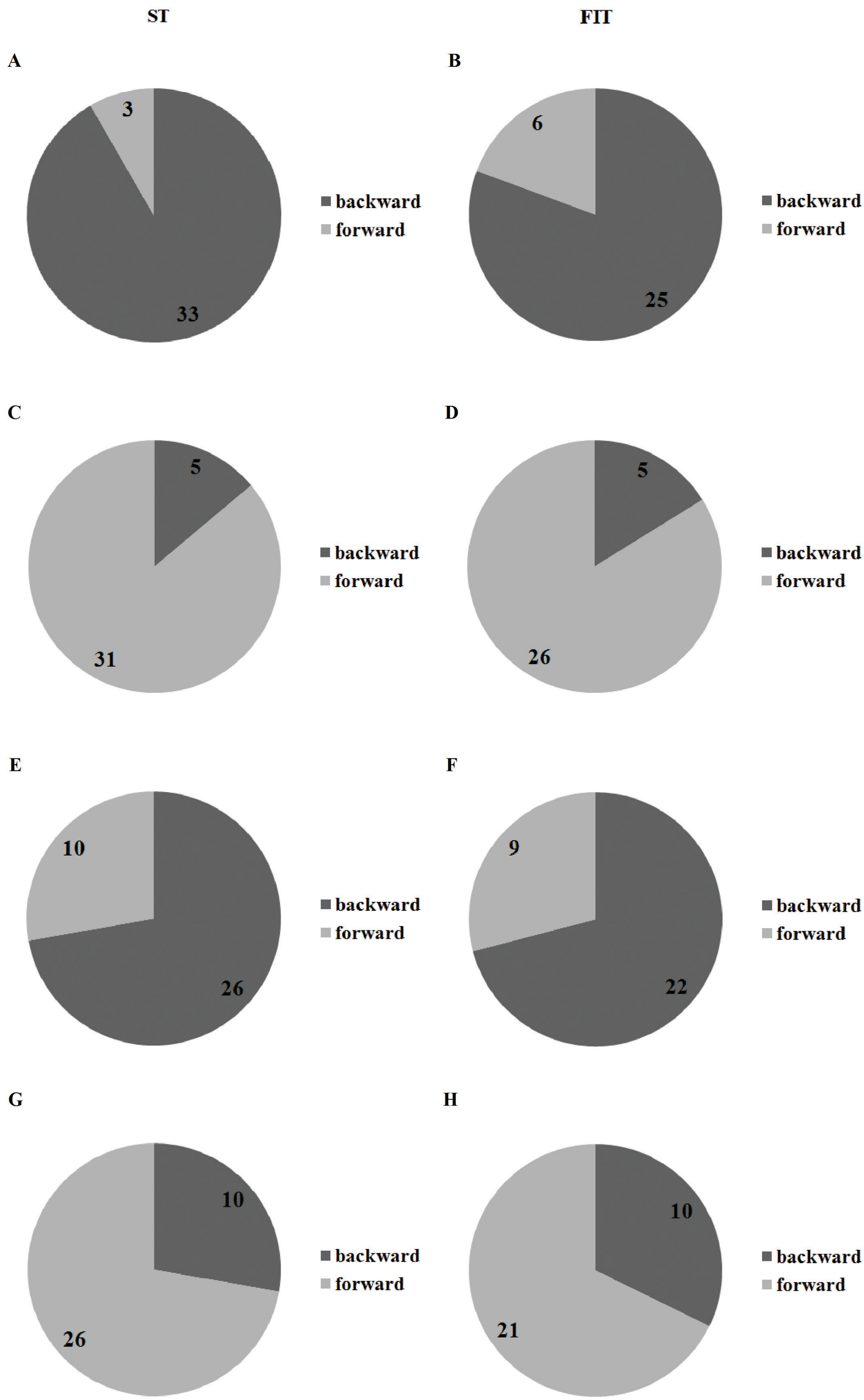

Fig. 3. - Position of BY in the four recordings. The diagram shows the number of subjects for ST group on the left and FIT group on the right. (A-B) Beginning of the 1st year. (C-D) End of the 1st year. (E-F) Beginning of the 2nd year, one group maintained the standard furniture (ST) while the other group changes it with the adjustable one (FIT). (G-H) End of the 2nd year.

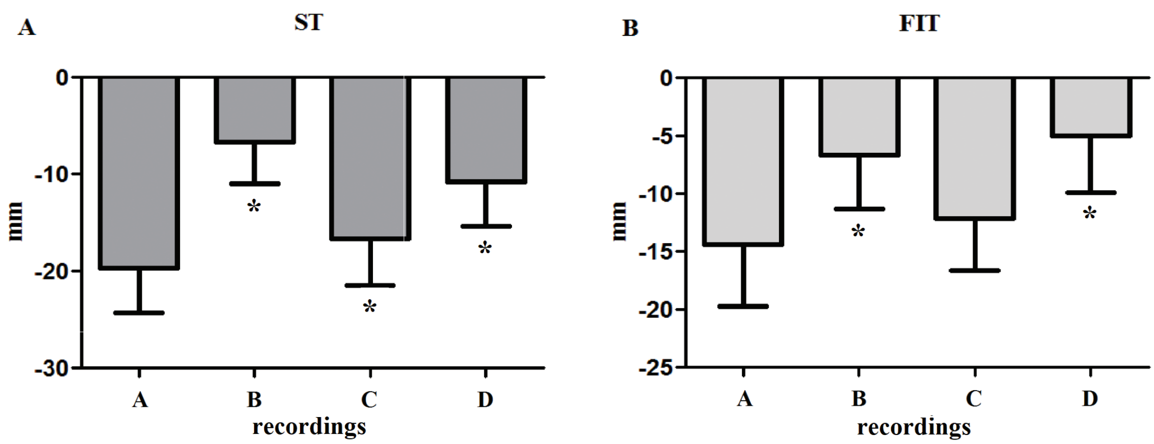

Fig. 4. - BY changes from one recording to the next. The diagram shows mean values ± 95% confidence interval for ST group on the left and FIT group on the right. In abscissa, (A) beginning of the 1st year; (B) end of the 1st year; (C) beginning of the 2nd year; (D) end of the 2nd year are shown. Values are expressed in mm. Significant post-hoc comparisons ($p<0.05$) are indicated with "*".

examination using a stabilometric platform has been carried out in a population of sixth to seventh-grade students at the beginning and at the end of each year. Starting from the second year, about half of the students adopted the furniture that follows the European rules of design established by UNI EN 1729:2006 to check if it could represent an adequate alternative to classic furniture aiming at preserving students' health.

Our research has shown that the use of the classroom furniture induces pronounced changes in the average position of the COP, especially in its antero-posterior dimension (BY). BY shifted forward at the end of the scholastic year compared to the beginning of it. Such displacements could be linked to the poor posture students adopt in the classroom, whose health implications are documented by numerous studies (see, for example, Parcells et al., 1999). Although not measured in the present study, we recognize that school furniture is too big for the average student who typically adapts to it assuming a slumped sitting posture. This could be reflected in the forward shifted standing COP we observed. The summer period, however, seemed to "reset" BY to its original position. Also, the lateral component of the COP (BX) shifted in opposite directions during successive years. We couldn't link BX modifications to anything relevant in the school environment. One possibility may be that students instinctively shifted their center of pressure from side to side in search of a better seating comfort or it can be an artifact of the recording procedure, given the relatively small sample size and the large standard deviations.

As far as we know, no similar results have been reported in the literature documenting any shift of the center of pressure resulting from daily use of school furniture. Such displacements could represent in and of itself a potential harm for the students' health given the compensations that may follow to ensure postural stability (Roussouly and Pinheiro-Franco, 2011). Such compensations start as alterations of muscular tone (for example a tightening of postural back muscles) and only afterwards they become permanent as the biomechanical structures of the body reach their final development. During growth, the spinal column progressively loses its flexibility and capacity to recovery its normal curves. The observed modifications affect both groups of students, suggesting that the improvements introduced by the European rules may not be sufficient to guarantee a correct sitting posture in the classroom. Additional investigations are necessary to fully determine the relative impact of the two kind of school furniture on posture.

Even though the UNI EN 1729:2006 has the great merit of drawing attention on the problem of the relationships between the school furniture and the anatomical structure of students, it fails to accommodate two important aspects of furniture design. The norm considers eight classes of furniture dimensions with regard to chair and desk height, seat depth and width, position of the backrest and of the armrest. Based on stature and popliteal height, each student is assigned to a specific class. The problem is that the furniture dimensions are not individually adjustable to take into account the fact that students may exhibit quite different anatomical compartments (Fubini, 2009). For example, two students may have the same height but one may have long legs and a short trunk while the other showing an opposite body structure. For that reason furniture should be "fine-tuned" to the student's bodily dimensions, allowing adjustments not only in fixed steps as the norm prescribes but in a continuous way. Careful attention should be made to the backrest of chairs. The suggestion to place a concave backrest at the level of the dorsal region is absolutely negative. The backrest should give instead support to the lumbar region and be convex in shape to help maintain the natural lordosis of the column. The 2012 reissue of the norm (UNI EN 1729:2006) has modified his prescriptions but the backrest is still not adjustable so that the most forward point of it (point S) does not always coincide, as it should be, with the 3rd lumbar vertebra (Kapandji, 1996).

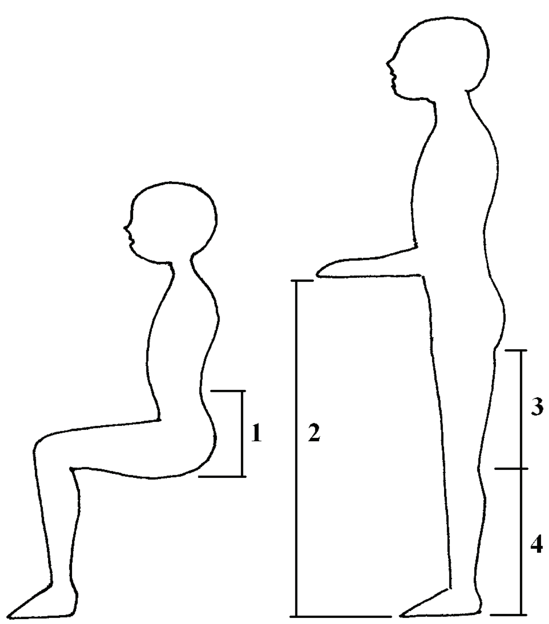

Fig. 5. - The four anthropometric parameters identified by us as critical to the design of adjustable furniture are depicted. (1) Point S height, (2) elbow height, (3) buttock-popliteal length, (4) popliteal height.

According to the norm all accessible edges of the furniture must be rounded and its surface smoothed. This is correct, but it would also be desirable to fill the chair with appropriate material in order to prevent paresthesia of the underside of the thigh derived from sciatic nerve compression or, even worse, venous thrombosis (Oyewole et al., 2010).

Finally, professors should care the general arrangement of the desks in the classroom to ensure that children don't stay with their head turned to one side for too long.

Figure 5 shows the four critical anthropometric parameters that, according to us, are to be considered in order to design innovative models of adjustable furniture that could correct the observed mismatch and be adapted to the developing children whenever it is needed. This will prevent assuming inadequate sitting postures that could contribute to the development of backache or other common musculoskeletal disorders.

Conclusions

The present study allowed us to single out some parameters that have to be considered in order to devise a new model of adjustable furniture. By adjusting every year the parameters of the furniture of each student, it would be possible to avoid (at least at school) the assumption of the wrong postural positions that could be responsible for musculoskeletal disorders in children and adults.

Conflict of interest

The authors declare that no conflict of interest exists.

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