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Coordination of School Science Classroom Furnishings with Anthropometric Parameters for 11-12 Year-Old Children

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ABSTRACT

The aim of the research was to explore the size suitability of school furnishings with the help of anthropometric measurements established on 11 - 12 year-old pupils. These pupils who have switched from single classroom teaching to teaching by subject and have lessons in specialized classrooms that are designed for a specific school subject. We were interested in the discrepancies between pupils' anthropometric dimensions and the size of school furniture in science classrooms. The study included 192 pupils (N = 192) in the 6th and 7th grades of primary schools in North-Eastern Slovenia. Readings were made of the pupils' anthropometric dimensions, including stature, popliteal height, buttock-popliteal length, elbow height sitting, thigh thickness, subscapular height and hip width. Measurements of the school furniture showed that the dimensions of desks designed according to ISO 5970 correspond to a size 6 (for those between 173 and 184 cm tall). Results of the anthropometric measurements have shown that 6th grade pupils are on average 152 cm tall, 7th grade pupils 160 cm. The research thus indicated a serious mismatch between school furnishings and the anthropometric dimensions, an issue which can have serious consequences for pupils' development.

Key words: interiors, school furniture, anthropometry, science, primary school

Usklajenost elementov šolskega interiera za poučevanje naravoslovja z nekaterimi antropometrijskimi parametri 11–12-letnih otrok

Izvirni znanstveni članek
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POVZETEK

Namen raziskave je bil ugotoviti ustreznost dimenzij šolskega pohištva z antropometrijskimi meritvami učencev, starih od 11 do 12 let. To so učenci, ki so z razredne stopnje prešli na predmetno stopnjo poučevanja in imajo pouk v specializiranih učilnicah, ki so namenjene za specifični predmet. Zanimala so nas neujemanja med antropometrijskimi merami učencev z dimenzijami šolskega pohištva, ki je nameščeno v naravoslovnih učilnicah. V raziskavo je bilo zajetih 192 učencev (N = 192) 6. in 7. razreda osnovnih šol iz severovzhodne Slovenije. Izmerjene so bile določene antropometrijske mere učencev, kot so telesna višina, poplitealna višina, kavdalna dolžina stegna, višina komolca, debelina stegna, subskapularna višina in bitrohanterična širina bokov. Opravljene meritve kažejo, da dimenzije stolov in miz, izdelanih po standardu ISO 5970, ustrezajo velikostnemu razredu 6 (za telesno višino uporabnikov med 173 in 184 cm). Povprečna višina učencev 6. razreda je 152 cm, učencev 7. razreda pa 160 cm. Raziskava je pokazala veliko neujemanje šolskega pohištva z antropometrijskimi merami 11–12-letnih otrok, kar ima lahko resne posledice v njihovem telesnem razvoju.

Ključne besede: interier, šolsko pohištvo, antropometrija, naravoslovje, osnovna šola

Introduction

Companies are increasingly aware that an adequate work environment is important to ensure employee working efficacy. It is now almost self-evident that the workspace should maintain the health and mental-physical wellbeing of employees from an ergonomic standpoint, while this is relatively neglected in schools. Since pupils spend a quarter of their day in school, and 80% of the time is spent doing their school work while seated, the pupils' work space and ergonomically designed furniture are of great importance. Classroom furniture affects children's posture, comfort, health and ability to learn.

Because of the many hours spent sitting in the classroom and studying at home, the motor abilities of pupils are decreasing, and owing to incorrect posture when sitting, their spines (Novak et al., 1995) are becoming curved. Even primary school children are turning into a more sedentary population. Classes, homework, school work and information technology are the reasons that children spend up to 10 hours a day sitting. A static-passive attitude has become typical for school children. Not surprisingly, analysis of systematic medical examinations of Slovenian children showed an increase in spinal (Fošnarič & Delčnjak Smrečnik, 2009) problems. There can be many causes, ranging from rapid and uneven growth and lack of exercise, to extensive sitting. What is more, this sitting may be incorrect, given the presence of un-ergonomically designed furniture.

If the school furniture is not ergonomically designed and does not meet pupils' anthropometric dimensions, it can cause physical strain, discomfort and poor physical posture (Novak et al., 1995; Lueder & Berg Rice, 2008). Inadequate school furniture is a co-influence on excessive muscle tension, the frequency of pain in the neck and back area, headaches and, as established, pupils' poor posture (Novak et al., 1995; Cardon et al., 2004). These problems may be exacerbated during the period of rapid growth - puberty. Pain in the lower spine occurs among taller teenagers. The use of mismatched furniture by adolescents poses a greater risk of spinal (Castellucci et al., 2010; Lueder & Berg Rice, 2008). problems. The mismatch of school furniture may also have other negative effects: learning may be ineffective because of an uncomfortable sitting position, pupils may lose interest, and this affects their mental health (Castellucci et al., 2010). In the case of improper seating, where the torso is bent forward, the strain on the spine is greater than when standing (Wilke et al., 2001). We can assume that, in the case of static sitting, the risk is greater of early degenerative changes in the spine and of back pain. In addition, individuals with a static sitting position experience a decrease in the stabilization of muscles in the lumbar-pelvic area. Research shows that there is often a mismatch between the various anthropometric measures of pupils and the school furniture that pupils use in class (Parcells et al., 1999; Castellucci et al., 2010; Panagiotopoulou et al., 2004; Gouvali & Boudolos, 2006; Fošnarič & Šterlek, 2008; Fošnarič & Obran, 2010; Saarni et al., 2007; Savanur & Altekar, 2007; Domljan et al., 2008). Of course, school furniture is not the only cause of pain and discomfort. However, research has shown that awkward and constrained sitting postures and poorly designed classroom furniture are important contributors to children's musculoskeletal discomfort. These considerations are particularly important given that childhood is a critical time to learn and develop good postural habits that can be practiced throughout a lifetime (Lueder & Berg Rice, 2008).

School furniture mainly consists of school desks, school chairs and a teacher's desk. Since education has no age limit, the population of users is diverse in all respects.

School furniture can be used by pre-school children as well as by adults. The school furniture is therefore expected to conform to a certain level of compatibility and to be age-appropriate to the user or his/her body height. Furniture that is used by a pupil for several consecutive hours has to meet the construction and design requirements of ergonomics as well as the requirements of each type of classroom organization. School furniture is divided into several size classes or groups. This area is covered by the standards for school furniture: the European standard SIST EN 1729-1:2006 and the international standard SIST ISO 5970:1996.

Primary school classrooms (pupils aged between 6 and 10) are today's traditional classrooms or the universal type of classroom and are ergonomically engineered specifically for pupils of that age. In the secondary school (pupils aged between 11 and 14), such universal classrooms are complemented by specialized classrooms intended for certain specific school subjects. School facilities must be designed according to modern ergonomics, and be particularly flexibly adaptable to different forms of school work and in line with certain physiological characteristics of children according to their age (Fošnarič, 2001). Although education in Slovenian primary school is divided in triads of teaching periods, classrooms in schools are divided into class teaching (from 1^{st} to 5^{th} grade) and subject teaching (from 6^{th} to 9^{th} grade). Although 6th grade pupils still belong to the second triad and have class teaching, certain school subjects are carried out in specialized classrooms designed for the specific subject. An example of such a classroom is the science classroom that is intended for teaching chemistry and biology and is therefore ergonomically adjusted to older pupils. In the system of subject teaching, one classroom is often alternately used by pupils from several grades and, consequently, of varied ages (from 11-to 15-year-old pupils) and body height, which makes equipping these rooms very complicated. This complexity of the biomedical and physical parameters in the system "furniture dimensions–pupil's measurements – classroom needs", calls for adjustability in order to preserve the pupil's health.

Children are currently subject to quite different sensory, cognitive and physical demands than they have faced before. Today's children are different from previous generations in many countries. They are often taller, heavier and less fit. Many children (particularly girls) are experiencing puberty earlier than previous generations, which can impact their potential for musculoskeletal pain and disorders (Lueder & Berg Rice, 2008). During puberty, teenagers gain about 15% of their ultimate stature and 45% of their final skeletal mass (Spear, 2002).

In early adolescence, the bones and spine are weak and vulnerable; adolescent growth is largely at the spine. In the early stages, the spine grows quickly, adding length without adding mass. Children and adolescents have varied back shapes and therefore require a range of backrest profiles (Lueder & Berg Rice, 2008).

Research aim

Research conducted among Slovenian children showed that the level of activity among pupils decreased with their age; the greatest decline is associated with the period of adolescence. Musculoskeletal system diseases are among the key health issues due to lack of activity. The *Health Statistics Yearbook* for 2009 indicates that 14.1% of children and adolescents have poor posture, and 8.7% of children and adolescents already have implied or expressed spinal deformities. At the same time, the prevalence of the sedentary lifestyle is on the rise. Slovenian children aged around 11 years, are seated during the school week--in school and while doing homework—for a total average of around 9 hours.

Even in our schools we want to achieve a comfortable, functional, healthy and safe working environment for children. Since inadequate school furniture co-influences the frequency of pain in the neck and spine area, and because this mismatch in the period of puberty may pose a higher risk, we have attempted to establish the varied physical proportions of 6th- and 7th -grade pupils. Great interest was aroused by the anticipation that there exists a significant discrepancy between pupils' anthropometric dimensions and the size of school furniture, because the furniture accords with a specific subject meant for pupils in the senior classes.

Research Methodology

Participants

The study included 192 (N = 192) pupils: 89 boys and 103 girls. Anthropometric measurements were made at various schools in the northeast of Slovenia. These were made from December 2011 to June 2012. Pupils included in the study were attending the 6th and 7th grades of primary school. They were between 11 and 13 years old; the average age of participants was 12 years and 2 months. The research sample consisted of volunteer subjects. After giving written and verbal information about the study to the school principal, written authorization was obtained from the teachers, parents and pupils.

Dimensions of classroom furniture

The dimensions of school chairs in the tables (Figure 1) were taken in the science classrooms. The science classroom is equipped for science classes and biology, chemistry and physics classes in the 8th and 9th grades of primary school. All measurements of school furniture were executed by the same measurer, according to the criteria for the following measurements:

Seat Height (SH): measured as the distance from the highest point on the front of the seat to the floor.

Seat Depth (SD): measured from the back of the sitting surface of the seat to its front.

Seat Width (SW): measured as the distance from the left to the right point of the sitting surface of the seat.

Upper Edge of Backrest (UEB): measured as the vertical distance between the middle point of the upper edge of the backrest and the top of the seat.

Seat to Desk Clearance (SDC): measured as the vertical distance from the top of the front edge of the seat to the lowest structure point below the desk.

Desk height (DH): measured as the vertical distance from the floor to the top of the front edge of the desk.

Desk Width (DW): measured as the horizontal distance between the lateral edges of the desk.

Desk Depth (DD): measured as the distance from the back to the front of the top surface of the desk.

These are the common measurements considered in furniture design based on ergonomic principles (Parcells et al., 1999; Castellucci et al., 2010). All dimensions are expressed in centimetres and were taken by the same measurer with a metal tape.

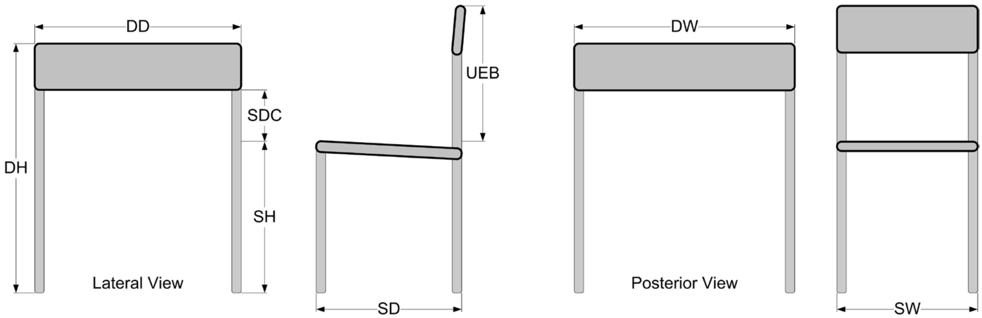


Figure 1: Presentation of classroom furniture measurements

Anthropometric measurements considered

The anthropometric dimensions, with the exception of height, were taken in the sitting position. The pupils were sitting in a relaxed, upright posture, without using the arm- or back-rest. The pupils were seated erect on a flat horizontal surface, with knees bent at 90°, and feet flat on a horizontal surface. The following human body dimensions, which are essential for sitting and work surface design (Panero & Zeinik, 1979) and taken into account (Castellucci et al., 2010; Pheasant, 2003) (Figure 2) were measured for this research:

Stature (S): determined as the vertical distance between the floor and the top of the head, and measured with the subject erect and looking straight ahead.

Popliteal Height (PH): measured with 90° knee flexion, as the vertical distance from the floor to the posterior surface of the knee or popliteal space.

Buttock-Popliteal Length (BPL): measured with 90° knee flexion, as the horizontal distance from the posterior surface of the buttock to the popliteal surface.

Elbow Height Sitting (EHS): taken with 90° elbow flexion, as the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface.

Subscapular Height (SUH): the vertical distance from the lowest point of the scapula to the subject's seated surface.

Thigh Thickness (TT): the vertical distance from the highest uncompressed point of the thigh to the subject's seated surface.

Hip Width (HW): the horizontal distance measured at the widest point of the hip in the sitting position.

All dimensions are expressed in centimetres.

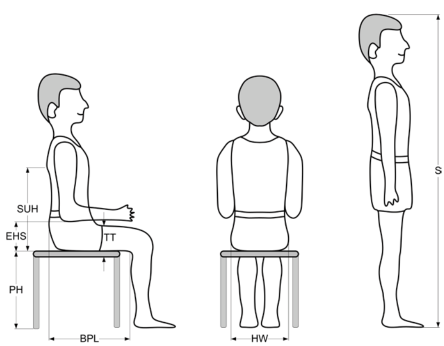


Figure 2: Explanation of the anthropometric measures

Application of the measurements

In order to establish the degree to which the parameters of school furniture and the pupil's dimensions were matching or mismatched, we analysed and tested the following criteria:

Popliteal height and seat height mismatch

The PH should be higher than the SH 1 but does not have to be higher than four centimetres or 88% of the PH in order to avoid compression in the buttock region. Based on existing research (Parcells et al., 1999; Castellucci et al., 2010; Panero & Zeinik, 1979; Panagiotopoulou et al., 2004; Cotton et al., 2002; Gouvali & Boudolos, 2006), we defined a mismatch of popliteal and seat height as any seat height that is either >95% or <88% of the popliteal height.

Buttock-popliteal length and seat depth

In order to be able to use the backrest of the seat to support the lumbar spine without compression, the match criterion was defined according to the equation (Parcells et al., 1999; Castellucci et al., 2010; Panagiotopoulou et al., 2004; Cotton et al., 2002)

$$0.80\ BPL \leq SD \leq 0.95\ BPL \qquad (1)$$

Hip width against seat width

To properly fit in the seat, the HW should be narrower than the SW. The match criterion is when the:

$$HW < SW \qquad (2)$$

Thigh thickness and seat-to-desk clearance

Parcells (1999) proposed that the desk clearance should be 2 cm higher than knee height. The match criterion was defined according to the equation (Castellucci et al., 2010):

$$TT + 2 < SDC \qquad (3)$$

Elbow height sitting against seat-to-desk height

This match criterion was defined with a modified equation (Castellucci et al., 2010) that accepts the EHS as the minimum height of SDH, in order to provide a significant reduction on spinal loading and considering that the maximum height of SDH should not be greater than 5 cm above the EHS:

$$EHS \leq SDH \leq EHS + 5 \qquad (4)$$

Subscapular height and upper edge of backrest

To be able to move the trunk and the arms correctly, the SUH should be higher than the UEB. The match criterion was defined according to the equation (Castellucci et al., 2010):

$$SUH \geq UEB \qquad (5)$$

Because this was a preliminary study, we chose the most commonly used and recommended relationships in the literature, which are those in Equations (1)-(5). The relationships used in this research are not the only ones available, but were considered most appropriate for our research.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) for Windows 16.0 statistical program was used for evaluation of the research data. In order to classify the data, frequency and percentage values were calculated. The arithmetic mean was calculated to identify the mean of the anthropometric measures. Standard deviation was calculated to identify the distance of the values in the distribution to the arithmetic mean. An independent t-test (with 95% confidence interval) was performed to examine the differences in measurements between 6th and 7th grade. For the analysis of the match between classroom furniture and proposed furniture, the χ 2 – test was used.

Results of research

Dimensions of classroom furniture

We measured the dimensions of school furniture in four primary schools in Slovenia. Measurements were performed in those classrooms adapted for the teaching of science subjects. The acquired measurements of science classroom school furniture are presented in Table 1 The measurements show that the dimensions of the chairs manufactured according to standard ISO 5970 in schools 1, 2 and 3 correspond to size 6 (for heights between 173 and 184 cm), in school 4 to size 7 (for body height above 185 cm). The school desks used for teaching science in all schools correspond to size 6. As shown in Table 1, we see a difference in the length of desks: 65 cm for a single desk and 130 cm for a double desk. The figures also reflect differences in the depth of desks, which does not affect the size according to the ISO standard, but the functionality of the usable surface. Desk width and depth are related to functional criteria such as the need for available surface, and not to any particular anthropometric measurement. In this case no criteria were defined to compare with anthropometric measurements.

Table 1. Dimensions of furniture (cm) in each school

FURNITURE DIMENSIONS	School 1	School 2	School 3	School 4
SH	46	45	44.5	50
SD	40	40	39	40
SW	38.5	38	38	38
SDH	31	31	30	26
SDC	12	11	28	12
UEB	40	40	40	40
DW	130	65	130	130
DD	60	50	50	50
DH	76	77	76	76

Legend: SH - Seat Height, SD - Seat Depth, SW - Seat Width, SDH – Seat-to-Desk Height, SDC – Seat-to-Desk Clearance, UEB - Upper Edge of Backrest, DW - Desk Width, DD - Desk Depth, DH - Desk Height

Anthropometric measurements of the pupils

The descriptive statistics for the seven anthropometric dimensions of the pupils are presented in Tables 2 and 3. Table 2 gives a summary of pupils' anthropometric measurements, and Table 3 shows the mean and standard deviation values for each class separately. As the data show, means and medians for most measures were almost identical, indicating highly symmetrical distributions. An Independent t-test (with a 95% confidence interval) was performed to examine the differences in measurements between 6th and 7th grade (pupils have science class in the same classroom and use the same furniture). The results show that there is a significant difference between 6th and 7th grade in Stature ($t = -7.132$; $p = 0.000$), Popliteal Height ($t = -6.035$; $p = 0.000$), Buttock-Popliteal Length ($t = -4.030$; $p = 0.000$), Hip Width ($t = -4.215$; $p = 0.000$), Thigh Thickness ($t = -2.712$; $p = 0.007$)

and Subscapular Height (t = -5.321; p = 0.000), but there isn't a significant difference in Elbow Height (t = -0.057; p = 0.9555). These results show that there is a difference between statures when considering different grades in primary school.

Table 2. Anthropometric measurements (cm)

PUPIL MEASUREMENTS (cm)	n	Mean	SD	Minimum	Maximum	Median
S	192	155.50	8.40	133	176.5	155.50
PH	192	42.17	2.07	37	52	42.00
BPL	192	43.48	3.38	34	53	43.00
EHS	192	18.97	2.66	12	27	18.50
HW	192	33.51	3.27	25	43	34.00
TT	192	13.09	2.09	9.5	20	13.00
SUH	192	35.89	2.54	29.5	44	36.00

Legend: S - Stature, PH - Popliteal Height, BPL - Buttock-Popliteal Length, EHS - Elbow Height Sitting, SUH - Subscapular Height, TT - Thigh Thickness, HW - Hip Width

Table 3 shows a consistent increase in mean by grade group. However, the standard deviations are almost the same, which isn't indicative of the greater variability that occurs as age increases.

There are two reasons, the first of which concerns the school system, where a 12-year-old pupil may be in the 6th or 7th grade. If these pupils are divided, instead of by grade, into age groups, the standard deviation increases. Thus, the average height of an 11-year-old pupil is 150.17 cm (SD = 7.18); the average height of a 12-year-old pupil is 157.47 cm (SD = 7.36). Since these are pupils in the period of early adolescence, which is characterized by accelerated physical growth, we found statistically significant differences in Stature between boys and girls. The girls sooner encounter the period of adolescence, and during this period they are taller than their male representatives. With 11-year-old pupils, we found a statistically significant difference in body height (t = -2.086, p = 0.040). Girls (159.01 cm) are taller than boys in this age group (155.87 cm). The difference according to gender is statistically significant for pupils in the 7th grade (t = -2.170; p = 0.033). Girls (161.26 cm) are taller than boys (158.01 cm).

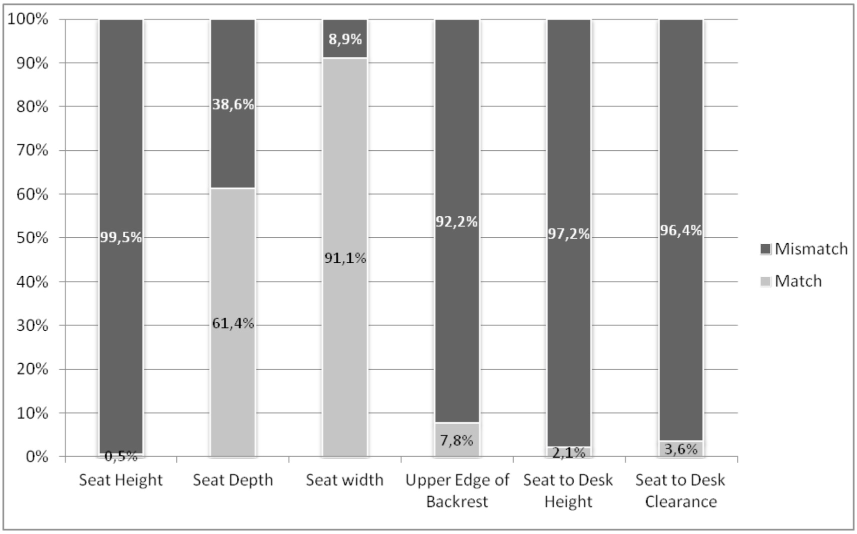
Table 3. Anthropometric measurements between 6^{th-} and 7th-grade pupils (cm)

	6th GRADE (n = 102)		7th GRADE (n = 90)	
	Mean	SD	Mean	SD
S	151.88	7.68	159.6	7.25
PH	41.39	2.08	43.05	1.68
BPL	42.59	3.35	44.48	3.13
EHS	18.96	2.71	18.98	2.63
HW	32.63	3.52	34.51	2.67
TT	12.71	2.07	13.52	2.04
SUH	35.03	2.24	36.86	2.51

Legend: S - Stature, PH - Popliteal Height, BPL - Buttock-Popliteal Length, EHS - Elbow Height Sitting, SUH - Subscapular Height, TT - Thigh Thickness, HW - Hip Width

Comparison between pupil body dimensions and classroom furniture

Graph 1 shows the percentage of pupils whose measurements matched or did not match the dimensions of the school furniture.



Graph 1: Percentages of pupils by match / mismatch level for the one-way criteria

It is obvious that the furniture used by pupils in science classes is too large and does not correspond to their anthropometric dimensions. The seat height is suitable for only one pupil (0.5%); for all other pupils, it is too big. The depth of the chair is suitable for 61.4% of the pupils, the width of the chair for 91.1% of the pupils. This information should not mislead us because the criterion that determines the appropriateness of the width of the chair is one-way. Insofar as the width of the chair is larger than the Hip Width, we are talking about the consistency of furniture. From the data above on the height and the depth of the chair, we can determine that the chairs used by pupils in the classroom are too large. Therefore, in the majority of cases we satisfied the criteria on the width of the chair and the Hip Width. In the case of the armchair height, desk height and leg clearance under the table, we find a predominance of mismatches (over 90%) between the dimensions of the furniture and the anthropometric dimensions of the pupils who use this furniture.

In Table 4, three categories were defined in the case of the two-way equations: a “Match” level when the anthropometric measurement falls between the limits; a “Too big” level when the minimum limit of the criterion equation is greater than the anthropometric measurement, and a “Too small” level when the maximum limit of the criterion equation is lower than the anthropometric measurement.

The seat is too high for as many as 191 pupils (99.5%). The depth of the chair is too great for 71 (37%) pupils, while, for three pupils (1.6%), the depth of the chair, according to their anthropometric dimensions, is too small. Because of one-way criteria, the width of the chair may be appropriate or too small. In our case the width of the chairs (because they are too big) in most cases (91.1%) is appropriate. Table 4 shows that the height of the Backrest is too high for most pupils, as well as the Desk Height.

When talking about the mismatch of school furniture, we find that in most cases it is simply too big. What surprises us is the information that the leg clearance under the table is inappropriate for most pupils (96.4%): it is too small.

Table 4. Dimensions of furniture design and match percentages

			Mismatch	
Design parameter	Dimension (cm)	Match	Too big	Too small
Seat Height	46	1 0.5%	191 99.5%	0 0%
Seat Depth	40	118 61.4%	71 37%	3 1.6%
Seat Width	38	175 91.1%	0 0%	17 8.9%
Upper Edge of Backrest	40	15 7.8%	177 92.2%	0 0%
Seat-to-Desk Height	30	4 2.1%	188 97.9%	0
Seat-to-Desk Clearance	12	7 3.6%	0 0%	185 96.4%

Figures 2 and 3 illustrate how the dimensions of school furniture correspond to the anthropometric dimensions of pupils by age. We showed the consistency of two chair dimensions: the depth of the chair and Backrest height. In both cases we see that the suitability of the furniture increases with the pupils' age. This confirms our previous findings that the furniture used by pupils in science classes is too big and does not correspond with their anthropometric dimensions.

Research has shown that the school furniture used by pupils in science classes is inappropriate to their anthropometric dimensions. For their size, more appropriate furniture would be items in accordance with ISO standard size 4; this is for pupils that are between 143 and 157 cm tall. We have portrayed it in the table with the mark NEW 4. Or size 5 furniture would correspond; this furniture is intended for pupils that are between 158 cm and 172 cm tall, and we indicate it in the table with the mark NEW 5. Table 5 shows the consistency of old furniture dimensions with anthropometric measurements and the consistency of the proposed furniture for this population of pupils. The χ 2 - test, proved a statistically significant difference in the case of Seat Height suitability (χ 2 = 148.606, p = 0.000), where new furniture with a seat size of 4 would be adequate for more than half the pupils. It also showed a statistically significant difference in compliance between caudal thigh length and the depth of the seat (χ 2 = 11.063, p = 0.001); a new set of seats in size 5 would fit 77.6% of the pupils. There would also be a greater difference in the number of pupils who would fit the previously mentioned new set of seats in terms of the height of the armchair (52.1%) in comparison with the existing set of furniture. There is a statistically significant difference (χ 2 = 87.587, p = 0.000). With a new set of desks and chairs in size 4, compliance of Seat-to -Desk Height with Elbow Height Sitting would increase. The compliance level of the proposed set would be 24%, which compared with the existing furniture (2.1%), also shows a statistically significant difference (χ 2 = 40.561, p = 0.000). In the case of the width of the chair, there is no statistically significant difference (χ 2 = 3.491, p = 0.062). More pupils would fit this width of chair than is true for the present set of chair seats.

Table 5. Classroom furniture and proposed furniture design and match percentages and χ^2- test

Design parameter		Match	Mismatch	n	χ^2-test	P
Seat Height	OLD	1 0.5%	191 99.5%	192	148.606	0.000
	NEW 4	109 56.8%	83 43.2%	192		
Seat Depth	OLD	118 61.5%	74 38.5%	192	11.063	0.001
	NEW 5	149 77.6%	43 22.4%	192		
Seat-to- Desk Height	OLD	4 2.1%	188 97.9%	192	40.561	0.000
	NEW 4	46 24.0%	146 76.0%	192		
Seat Width	OLD	175 91.1%	17 8.9%	192	3.491	0.062
	NEW 5	162 84.4%	30 15.6%	192		
Upper Edge of Backrest	OLD	15 7.8%	177 92.2%	192	87.587	0.000
	NEW 5	99 52.1%	93 47.9%	192		

Discussion

The results indicate a mismatch between the body dimensions of pupils participating in this study and the school furniture available in science classrooms. Our school furniture measurements showed that the dimensions of desks designed according to ISO 5970 correspond to size 6 (for heights between 173 and 184 cm). Results of the anthropometric measurements showed that 6th-grade pupils are on average 152 cm tall, 7th-grade pupils 160 cm tall. The dimensions of the school desks used in science classes are inappropriate according to their body height. Desk height is suitable for only 2.1% of these pupils. Similarly, a complete mismatch was also found by Castellucci (2010) in Chilean children, where Seat-to-Desk Height was too high, and there was a mismatch for 99% of the pupils. The mismatch in desk height was also proven for 99% of Gaza Strip students (Agha, 2007). Although pupils are using desks that are too high for them, the survey showed that the space clearance under the desk is inadequate, because it is too small. The cause of the mismatch between the under-desk clearance and the thickness of the thigh lies in the shelving or wire racks that are located under the desk and to serve for storage and retrieval of school supplies. Seat-to-Desk Clearance showed a mismatch for 96% of the pupils. This situation of mismatch produces mobility constraint because of contact between the thighs and the desk. Other studies from Parcells (1999) and Gouvali and Boudolos (2006) show 0% and 5.8% of pupils with desk clearance problems; this difference could be due to extra shelving and wire racks under the desks of Slovenian pupils. Seat Height, which is the starting point for the design of classroom furniture and also the measurement used for prescription of a set size, was not appropriate for this population of pupils. An example of a clear mismatch between the seat height and popliteal height is presented in Figure 4. These pupils (99.5%) were using a higher seat that is appropriate for pupils with heights between 173 and 184 cm, so they would be unable to support their feet on the floor, and that increases tissue pressure on the posterior surface of the knee. So, we can talk about chairs that are too high or a height mismatch. These results are similar to those from a study done on Hong Kong school children aged 10-13, where 93% of pupils have chairs that are too high (Chung & Wong, 2007).

Over-sized chairs are also characteristic of pupils in Chile, where the mismatch was ranged between 72% and 86%, depending on the set of chairs (Castellucci et al., 2010). The majority of Greek pupils are sitting on chairs that are too high for them (Panagiotopoulou et al., 2004). Since the chairs used by pupils are too big, most of them have no problems with seat width, which complies in 91.1% of the pupils. Correlation between caudal thigh length and the depth of the chair is 61.4%. For more than a third of pupils, a chair of these dimensions is inadequate. Since the chairs used by pupils are too big and too high, they tend to place their buttocks forward on the edge of the seat, especially while reading and writing. The lack of back support in this position causes a slumped, kyphotic posture. Research studies (Wilke et al., 2001) have shown that in sitting with the torso bent forward, the burden on the spine increases even more than if the pupils were standing. The height of the backrest is suitable for only 7.8% of the pupils. Wilke (2001) demonstrated that the use of a backrest reduces pressure on the intervertebral spinal discs. In our case, where the height of the backrest is inappropriate for the pupils and there are no height-adjustable seats, this could be a major problem and the cause of subsequent back problems.

Figure 3: A clear mismatch between popliteal and seat height. Feet are not on the floor.

Since the dimensions of the desks and chairs used by pupils in the classroom are too big and because the independent t-test showed statistically significant differences in anthropometric measurements among 6^{th}- and 7^{th}-grade pupils, we can conclude that furniture suitable for 6th-grade pupils is inappropriate for 7th-graders. We have also demonstrated a statistically significant difference between the existing and proposed set of furniture in favour of the proposed set. It is unacceptable that pupils who differ in height (from 133 cm to 176.5 cm) have furniture of the same size. The consequences of the inadequacy of school furniture can include negative effects on their development, particularly on children during the early adolescent period of rapid growth.

In the SIST EN 1729-1:2006 standard, those product dimensions are particularly specified that are important both for ergonomic compliance with the user's height and for their mutual coherence. School furniture is divided into eight size categories, but the Slovenian schools are equipped with school furniture of only four different size dimensions. Classrooms are generally equipped with one size of school furniture, regardless of the variability in pupils' height. In an ideal world, every pupil should have a height-adjustable, ergonomic chair and desk, but for very low costs we could improve the situation by installing furniture of various sizes in the existing classrooms. The aim of the research was not to demonstrate the mismatch between school furniture and the anthropometric dimensions of pupils, but to highlight the problem when the younger pupils, physically vulnerable early adolescents, attend lessons in subject-specific classrooms (such as the science classroom), aimed at the older, larger children. We believe that, with the exception of this particular problem, that there does not exist a large mismatch in Slovenia between school furniture dimensions and anthropometric measurements of the pupils.

For various reasons, we are increasingly becoming a sedentary population. Our children spend on average 9 hours a day seated in school and doing their homework during the week. It is necessary to reduce the daily physical demands on schoolchildren by changing the traditional mode of teaching for the dynamic method of teaching involving the movement of children. Research by Cardon (2004) evaluating the differences in classroom sitting habits during the "Moving School" project and in traditional schools showed that pupils in traditional schools spend 97% of classes being static. We can ask ourselves what may be the health consequences if pupils in these classes also have inadequate furniture. Purchasing ergonomic furniture represents for schools a major financial undertaking. It is also necessary to consider the structural and organizational resources that would make classes more dynamic through pupil mobility.

Conclusion and teaching implications

Research has shown that the school furniture used by Slovenian 6th- and 7th-grade pupils in science classrooms does not accord with their anthropometric dimensions. The furniture is inappropriate because science instruction takes place in classrooms specially set aside for biology, chemistry and physics, in classrooms that are designed and equipped for older pupils. Thus, the school furniture that pupils use is too large. As we found in the survey, pupils at this age vary greatly in their anthropometric dimensions, so it is unacceptable to use one-size furniture that does not match their anthropometric dimensions. Inadequacy in school furniture can result in back problems and poor posture and can have negative consequences on children's development.

The mismatch between pupils' anthropometric characteristics and the dimensions of school furniture would be eliminated or at least reduced by installing furniture in various sizes. This would reduce the physical burden in the school environment.

Teachers need to be educated to identify pupils in obviously ill-fitting school furniture and facilitate assignment to more appropriate seating whenever possible. It would be necessary to respect the basic principle that says that it is necessary to adapt the workplace to the human being and not vice versa. We could also reduce the burden on children by choosing appropriate or changed pedagogical methods of work that would balance the traditional form of school learning with dynamic posture and dynamic sitting. Children's need for movement must be met, so we should direct the teaching process so that we reduce static sitting and increase the methods of work that involve movement, walking around the classroom, learning to stand and dynamic sitting on and at height-adjustable chairs and desks.

A classroom should be based on a specific design that respects the ergonomic features adjusted to the anthropometric dimensions of pupils and fulfils the needs for active, dynamic and physical behaviour. Only in this way will we ensure the healthy physical, mental and emotional development of children.

Limitations

This research was carried out in 2012. Anthropometric measurements were made at various schools in the northeast of Slovenia. Anthropometric measurements can vary according to geographical region and year. Consequently, the fact that the sampling group constitutes only a small sample is a limitation of the study.

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