Coll. Antropol. **32** (2008) 1: 257–265
Original scientific paper

Classroom Furniture Design – Correlation of Pupil and Chair Dimensions

Danijela Domljan[1], Ivica Grbac[1] and Julijana Hađina[2]

[1] Department for Furniture and Wood Product, Faculty of Forestry, University of Zagreb, Zagreb, Croatia
[2] Department of Anatomy and Physiology, Health Polytechnic, Zagreb, Croatia

A B S T R A C T

The present study aimed at determining the relationship of anthropometric dimensions of pupils from grades 1 to 8 in primary school with the dimensions of school chairs. Two dimensions of the chairs in daily use were evaluated to ascertain whether the fit is sufficient and the effect on pupils' sitting posture. The work included a sample of 556 pupils from three primary schools in Zagreb, Croatia and two types of furniture. Dimensions of school chairs were compared with three anthropometric variables of the pupils. Descriptive statistics were analysed for all variables. These study results have shown that furniture of appropriate dimensions is not available to a large number of students in Croatia. Currently supplied classroom equipment is provided in only two sizes and does not fit the users. It is recommended that task chairs may be acceptable if they are issued in four heights or individually adjustable chairs be introduced in Croatian schools. Furthermore it is strongly recommended that schools actively promote appropriate active sitting behaviour.

Key words*: primary school, classroom furniture, anthropometry of pupils, chairs dimensions, sitting*

Introduction

The first days of school represent a turning point in the life of every child. This marks the end of self-directed alternating play and rest periods. Work organization becomes the main concern, and work is carried out in fixed postures and under restriction of free movement[1]. School youth are nowadays a special risk-group. Contemporary school-aged children might spend 30% of their waking hours at school, mostly sitting[2]. Of all the working positions in the classroom environment, majority are forward (reading and writing, 57%) and backward (listening the teacher or watching the blackboard, 43%)[3]. In school furniture design the »sitting problem« and children's behaviour are very complex issues[4]. School time is the period when sitting habits are developed. Subsequent change of incorrect learned sitting posture[5] is very difficult. For primary school pupils adjustable furniture does not automatically equate to »ergonomic« design. However, fit and training in sitting posture is of the utmost importance. Most children do not know anything about the proper prolonged sitting behaviour, so they need proper education on sitting behaviour. If furniture is adjustable they need instruction on the adjustment mechanisms and the importance of fit.

Prolonged sitting (e.g. uninterrupted 90-minute sitting during double sessions) is a most significant strain to a young body and a cause of physical fatigue. Non-ergonomically dimensioned furniture, unsuited to body dimensions, increases physical strain, and commonly results in irregular posture[6]. This generates muscular back, neck and head pains, loss of concentration and restlessness in the attempt to find a better position. About 25% of the UK students complain about back and neck pains, headaches and loss of concentration. The US schoolchildren manifest lower back pain or other musculoskeletal disorders (referred to as LBP/MSD)[7]. An increasing number of children have been found to report musculoskeletal discomfort. This has triggered studies that have found school desks and chairs are designed inadequately in relation to the pupils' body dimensions, which is one of the key contributors to sitting discomforts[8]. A number of studies[2,9–12] confirm the mismatch between anthropometric dimensions of pupils at different ages and dimensions of classroom furniture. The mismatch is closely related to incorrect sitting posture and may be a predictor of back pain and future disorders. Disorders developed during academic years may have permanent consequen-

Received for publication December 1, 2006

ces to the human body and subsequently lead to significant problems during sitting and office work[13].

Current approaches to designing pupil's work place do not fully support up-to-date needs of contemporary academic generations[14]. Some authors have tried to define appropriate dimensions for school furniture and the sitting posture. They have made recommendations that relate school furniture dimensions to pupil's anthropometry. However, their approach to school chairs and desks design is still on the theoretical level, mostly observed in 2D, not in 3D geometric space. Design of the »classroom working environment« in most schools is still traditional. Innovative solutions based on different approach to sitting posture[15] are perceived by some education officials to be excessively innovative and expensive for traditional bureaucratic systems[16].

In the relationship between »furniture – pupil – classroom – school system« some of the issues are: new teaching standards, new construction requirements for academic structures, inherited habits of bureaucratic educational system, financial capability of governments to provide school equipment, awareness of correct sitting, new achievements which ensure optimal sitting posture, etc. One of the most important requirements for school chair and task table design is the relation between users' anthropometry and furniture functional dimensions.

Anthropometric dimensions of pupils

Anthropometric dimensions of pupils should determine the standards and functional dimensions of school furniture[7]. Optimal size of school desks and tables and other dimensional parameters of the environment interacting with pupils' dimensions are best determined on the basis of both static and dynamic anthropometric characteristics of the range of pupils' dimensions. International standards EN 1729–1[17] applied in Croatia as HRN ENV 1729–1:2003[18] are currently the best source of design solutions to and functional dimensions of school desks and chairs, especially as regards double-sloped seats and high sitting. A new draft version PrEN 1729 issued in 2003, drawn up by CEN/TC 207 »Furniture«, is under revision and can be improved with new approaches[19].

During the school years the human body experiences rapid growth and development. The problem is that anthropometric dimensions of the Croatian youth differ from the youth in other countries[20,21]. Distribution curves of youth anthropometric variables show wide variances within the population. Differences in height differ amongst schools, regions, and countries even accounting for gender and age[1,22]. The growth curve varies the most from ages 11 to 14 years. This happens at a time when class teaching carried out in a well-known environment of one classroom at the same worksurface (from grades 1 to 4) is replaced by subject teaching with classroom switches (from grades 5 to 8). In the system of subject teaching one classroom is often alternately used by the pupils of several grades and, consequently, of different age and body height which makes equipping of these rooms very complicated. This complexity of the biomedical and physical parameters in the system »furniture dimensions – pupil's measurements – classroom need«, calls for adjustability in order to preserve the pupils' health.

Over the past 30 years body height of pupils between the ages 6 to 14 has increased by as much as 3 cm (the mean value)[21,23]. According to that, new anthropometric data the body height of the 95-percentile pupils 7 year old to the 95-percentile pupils 18 year old reached from 95 cm to 185 cm. Differences is almost 70 cm. The surveys of the secondary school youths in Croatia from 1973[1] and the most recent one from 2002[4] show that the students' average height has increased by more than 6 cm (boys) and by nearly 8 cm (girls). Over the last 30 years in primary schools of Croatia, the average height of pupils from 7 to 10 years has increased by 5 to 8 cm, and for pupils from 11 to 14 year old the average height increased by even 7 to 10 cm[1,25–27].

Therefore, task furniture in classrooms should accommodate accordingly. Annual anthropometric measurements however, are hardly feasible for financial and practical (physical) reasons in many countries. In Croatia during annual compulsory check-ups of the young only body height and weight are recorded. These data are seldom systematically recorded or provided to schools that decide about the dimensions of the furniture to be purchased[28]. Unfortunately, height and weight data alone is not useful guidance for selecting furniture to purchase because body proportions vary. One student may have long legs and a short torso while another has a long torso and short legs even though they are the same height. Popliteal height and buttock to popliteal length measurements are much more relevant for chairs, but those variables are never measured during compulsory check-ups, or during physical trainings at schools. They have never been used for purchase school furniture in classrooms.

Classroom equipment

Proper design of school desks and chairs compliant with ergonomic principles has a major effect on working capacity and performance. Determining design and equipping schoolrooms with properly sized furniture is not easy due to the aforementioned alternating shifts through one classroom and absence of relevant anthropometric measurements.

Irrespective of recommendations to have school desks and chairs ergonomically designed and adjustable to their individual users[29] the majority of countries have not abandoned their mass production of furniture. In UK schools, as much as 86% of school desks and chairs are unfit for use (old and worn out, non-ergonomically designed, unsafe, even dangerous)[30]. About 90% of the Croatian schools are equipped with old furniture, manufactured according to the outdated ISO standards from the year 1979; ISO 5970/1979; or the Croatian standards from 1989; HRN D.E4.201/1989[14,24].

Present study

This study is aimed at determining to what extent the available school chairs in the studied primary schools meet the needs of a specific population from grades 1 to 8, and to point out possible misuse of task furniture in their classrooms. The purpose of the study was to examine whether the dimensions of furniture, notably of chairs affect pupils' sitting posture and whether they are appropriate for healthy development of young human bodies. Differences in gender are analysed, but in this study are not observed. Given the scope of the available data, this work shows analytical results of the variables for height, width and depth of the used task chairs and the applied anthropometric dimensions (popliteal height, upper leg length and hip breadth) considered as competent variables for establishing seat dimensions, in determinations whether the furniture dimensions are adequate for pupils' posture.

Material and Methods

The study, carried out from 2004 to 2006, included 556 pupils (293 boys and 263 girls) from grades 1 to 8 at three primary schools in Zagreb, Croatia. The selected primary schools differed in the teaching approach (traditional public school; private school; alternative school), classroom equipment (old and lower price furniture; new and higher price furniture) and the number of pupils in a class (from 2 to 32). All schools had classrooms equipped with the task furniture for daily use, which had been produced in Croatia.

Dimensions of school task chairs

Dimensions of school task chairs were taken in the classrooms (at the point of use). Functional dimensions were recorded according to the standard HRN ENV 1729–1:2003. Three ergonomic parameters (variables) important for proper design of the chair seat were recorded and labelled as shown in Figure 1, and were measured as the following:

- *Seat height* (h_8): was measured as the distance from the highest point on the front seat to the floor.
- *Seat depth* (t_4): was measured from the back of the sitting surface of the seat to its front, with the possible inclination of +/– 20°.
- *Seat width* (b_3): was measured as the distance from the left to the right point of the sitting surface of the seat.

All dimensions are expressed in centimetres.

Anthropometric dimensions of the pupils

In all three schools the subjects were healthy pupils of the average age by grades from 7,0 to 14,5 years.

Anthropometric dimensions, with the exception of height, were taken in sitting position (after Panero and Zelnik)[31], on the usually used two task chairs of two different heights, on a flat and adjustable horizontal floor surface. The lower types of chairs were used for measurement of pupils from 1 to 4 grades, and the higher types of chairs were used for the 5 to 8 graders. The pupils were sitting in relaxed and erected posture; without using arm- or back-rest, wearing T-shirts and tight-fitting garment for gym or shorts; with their upper body vertical to the sitting surface; upper legs horizontal to the floor and the seat, perpendicular to the body and with the upper arms and elbows horizontal to the floor. Static anthropometry reference points for sitting variables F, D and L, were measured as the following:

- *Buttock-popliteal length, upper leg length* (D): was measured as the distance from the posterior surface of the buttock to the posterior surface of the knee or popliteal surface.
- *Popliteal height* (F): was measured as the vertical distance from the foot resting surface to the popliteal space (the posterior surface of the knee)
- *Hip breadth* (L): was measured as the maximal distance between the outside points at hips when seated.
- *Stature* (A): body height was measured as the vertical distance from the floor to the top of the head, while the pupil stood erect, looking straight ahead.

Figure 2 shows the variables selected and analyzed. All dimensions are expressed in centimetres.

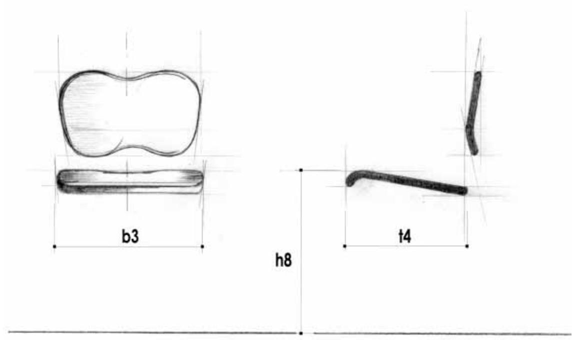

Fig. 1. Functional dimensions of the seat of a school task chair. h8 – seat height, t4 – seat depth +/– 20°, b3 – minimum seat width (according to the HRN ENV 1729–1:2003).

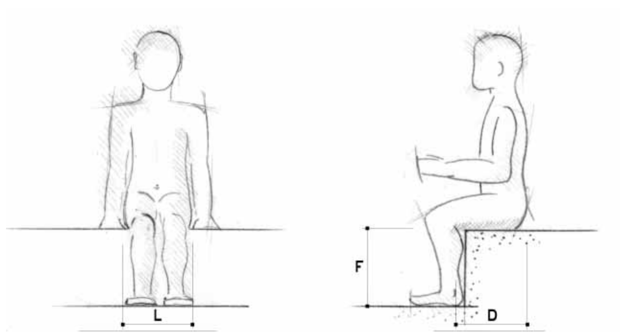

Fig. 2. Anthropometric dimensions of the pupils. Measured variables: D – upper leg length, buttock-popliteal distance, seated, F – popliteal height, seated, L – hip breadth, maximum when seated.

Statistical methods

In order to find out how much the main parameters of school task chairs and the pupils' dimensions match or mismatch each other in ensuring ergonomically proper posture, we analyzed and tested the following variables of the chairs and the subjects.

- F (popliteal height, seated) – h_8 (seat height)
- D (upper leg length, buttock-popliteal length, seated) – t_4 (seat depth)
- L (hip breadth, maximum when seated) – b_3 (seat width)

Descriptive statistic was made for all analyzed variables. All analytical errors type I (α) accounting for 5% were considered statistically significant.

For comparison of the pupils' anthropometric dimensions with dimensions of the corresponding furniture types the hypothesis was tested about arithmetical mean of the reference group[32]. The differences in the pupils' popliteal height by grades were tested by variance analysis. Wherever the differences were statistically significant, Scheffe's post hoc test was applied to determine between which grades they existed.

A comparative table was designed denoting sizes from the HRN ENV 1729–1:2003 standard in order to define size mark within the newly recognized groups. Statistical analyses and graphs have been made in the statistical package STATISTIKA 6.0.[33].

Results

Dimensions of school task chairs

The analysis of school chairs in every school included in this study identified eight different chair types. The differences were in type and dimensions of the materials, shape and construction of the chair base, and functional dimensions. With the aim of simplifying statistical evaluation we neglected minor differences in shape, construction and material make. All chair types were brought to the two basic design-constructional types (groups *a* and *b*) and two heights (lower group *l* and higher group *h*). Combinations of the groups (*al* and *bl*, and *ah* and *bh*) were compared with the pupils' dimensions. Further analysis was focused on the sizes h8, t4 and b3, as shown in Table 1. One can see that all values in both groups, with the exception of h8 variable in *al* and *bl*, were mutually different. This enabled further statistical analysis of the higher and lower chair groups.

Anthropometric dimensions of the pupils

The data regarding anthropometric dimensions F, D and L were analyzed according to the grades. Table 2 shows descriptive statistics (Mean, Standard deviation, Standard Error of the Mean, Lower 95% CI and upper 95% CI) of all the three analysed variables.

The results showed that the mean of every variable and the corresponding standard deviation increased with the age, having more marked inclination in grades 1 and 5. Consequently, furniture dimensions for every grade should »increased« and be grouped accordingly.

Results of statistical evaluation

Comparison results in the parameters were tested among the pupils from grades 1–4 and 5–8, and shown in Table 3.

The difference in popliteal height when seated between the pupils from 1–4 and 5–8 grades showed a statistically significant difference ($F(1.559)=411.5$; $p<0.001$) (Figure 3).

TABLE 1
MEASURED PARAMETERS OF THE STUDIED TWO GROUPS OF SCHOOL TASK CHAIRS

	Chair type	Dimensions (cm)			Group / Description
		h8 (height)	t4 (depth)	b3 (width)	
	ah al	44 38	40 39	36 36	Backrest & seat veneer panel 6 mm, PU nature lacquer; backrest with the lumbal support and radius in median plane, seat with the radius at the transverse plane; welded lacquered steel construction of the base 20×30 mm, skies, lacquered blue; PVC black stops, recessed head screws.
	bh bl	47 38	41 35	36.5 32	Backrest & seat veneer panel 5 mm, PU nature lacquer; backrest with radius in median plane, seat with the radius at the transverse and median plane; welded lacquered steel construction of the base ø20 mm, 4 legs, lacquered blue; PVC black stops, recessed head screws.

al – lower *a* type of the chair, *bl* – lower *b* type of the chair, *ah* – higher *a* type of the chair, *bh* – higher *b* type of the chair

TABLE 2
ANTHROPOMETRIC DIMENSIONS OF THE VARIABLE F, D AND L

	N	F – popliteal height (cm)					D – buttock – popliteal distance (cm)					L – hip breadth (cm)				
		MV	SD	SE	L95% CI	U95% CI	MV	SD	SE	L95% CI	U95% CI	MV	SD	SE	L95% CI	U95% CI
Total	556	40.99	4.56	0.19	40.61	41.37	40.44	5.08	0.22	40.02	40.86	32.15	4.61	0.20	31.76	32.53
Male	293	41.18	5.02	0.29	40.60	41.76	40.07	5.13	0.30	39.48	40.66	32.52	5.01	0.29	31.94	33.09
Female	263	40.77	3.99	0.25	40.29	41.25	40.85	5.01	0.31	40.24	41.46	31.74	4.09	0.25	31.24	32.23
Grade 1	55	34.81	4.84	0.65	33.50	36.12	33.88	4.54	0.61	32.66	35.11	27.56	2.71	0.37	26.83	28.30
2	70	37.24	2.86	0.34	36.55	37.92	36.56	4.48	0.54	35.49	37.62	28.85	2.41	0.29	28.27	29.43
3	75	38.40	2.44	0.28	37.84	38.96	38.12	2.33	0.30	37.58	38.66	30.09	2.91	0.34	29.42	30.76
4	92	40.60	2.94	0.31	39.99	41.21	39.83	2.55	0.27	39.30	40.35	31.15	3.40	0.35	30.45	31.86
5	69	42.23	2.64	0.32	41.60	42.87	41.15	3.04	0.37	42.42	41.88	32.39	4.14	0.50	31.40	33.39
6	67	43.68	2.33	0.28	43.11	44.25	43.56	3.06	0.37	42.82	44.31	33.98	3.11	0.38	33.22	34.74
7	78	45.33	2.70	0.31	44.72	45.93	44.90	4.26	0.48	43.94	45.86	36.96	4.41	0.50	35.96	37.95
8	50	45.52	2.90	0.41	44.70	46.34	45.58	3.98	0.56	44.45	46.71	36.43	3.92	0.55	35.32	37.54

MV – Mean Value, SD – Standard Deviation, SE – Standard Error, L95%CI – Lower 95.00% Confidence Interval, U95%CI – Upper 95.00% Confidence Interval

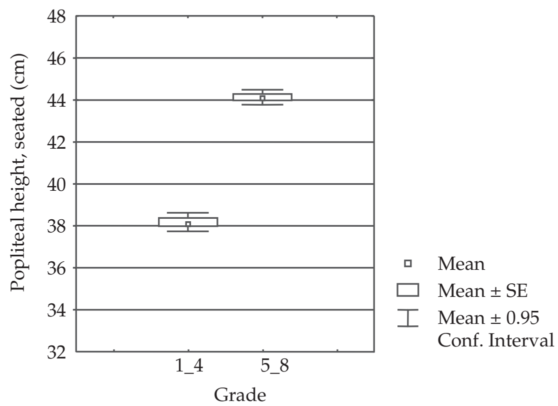

Fig. 3. The differences in popliteal heights of the seated lower- and higher grade pupils.

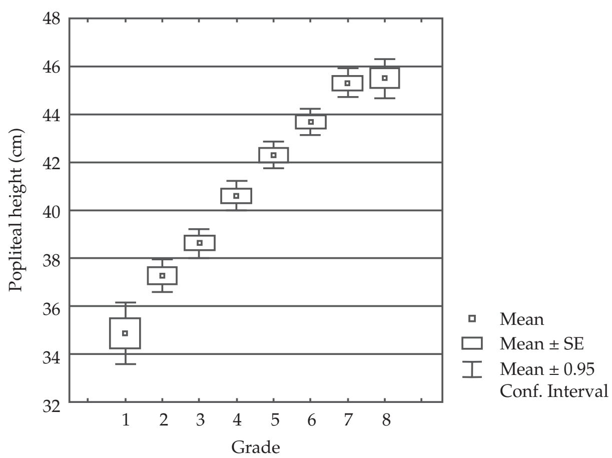

Fig. 4. Differences in popliteal height of the 1–8 grade pupils when seated.

This information is in support of equipping primary school classrooms with two different height chairs (which is also found in our three schools), of which the lower ones are for lower grade pupils (1–4) and higher ones for higher grade pupils (5–8).

Testing of the same height chairs in both grade groups of pupils separately (from 1–8) showed a statistically significant difference in the popliteal height when seated ($F(7.553)=105.3$; $p<0.001$) (Figure 4).

Scheefe's post hoc test (Table 4) showed statistically significant differences between grade 1 pupils and other grades. Consequently, these pupils formed a separate, distinguished group. Grade 2 pupils were not statistically different from grade 3, but the latter was statistically different from grade 4. Another group would have comprised grades 2 and 3. Grades 4 and 5 did not show statistically significant differences as did grades 5 and 6, whereas grades 4 and 6 were different. Statistically, grade 6 was not significantly different from grades 7 and 8. Grade 6 could form the group with grades 4, 5, 7 and 8.

According to the newly established classification, which suggests introduction of four additional seat heights fitted to the pupils' dimensions, the comparison was made between the new suggested dimensions (group 1–4) and the variable h8 applying HRN ENV 1729–1:2003 reference standard. The results are shown in Table 5.

Discussion

Based on our study results the following can be discussed:

Test results of F and h8. Popliteal height between two groups of pupils, grades 1–4 and 5–8, show and confirm sufficiency of only two statistically significant height groups i.e. grade groups 1–4 and 5–8 (lower and higher)

TABLE 3
COMPARISON OF THE STUDIED VARIABLES FOR LOWER AND HIGHER GRADE GROUPS

Chair type		GRADES 1–4 (n=293)			GRADES 5–8 (n=263)		
	μ_0	$\bar{X} \pm$ S.D.	t	p	$\bar{X} \pm$ S.D.	t	p
	h8	F	H_0: $\mu=\mu_0$		F	H_0: $\mu=\mu_0$	
al	38	38.199 ± 3.864	0.886	0.376	44.136 ± 2.941	33.907	<0.001
bl	38		0.886	0.376		33.907	<0.001
ah	44		–25.873	<0.001		0.753	0.452
bh	47		–39.253	<0.001		–15.823	<0.001
	t4	D	H_0: $\mu\geq\mu_0$		D	H_0: $\mu\geq\mu_0$	
al	39	37.481 ± 4.027	6.499	>0.999	43.710 ± 3.977	19.242	>0.999
bl	35		–10.620	<0.001		35.582	>0.999
ah	40		10.779	>0.999		15.157	>0.999
bh	41		15.058	>0.999		11.071	>0.999
	b3	L	H_0: $\mu<\mu_0$		L	H_0: $\mu<\mu_0$	
al	36	29.657 ± 3.216	–33.989	>0.999	34.907 ± 4.356	–4.077	>0.999
bl	32		–12.557	>0.999		10.845	<0.001
ah	36		–33.989	>0.999		–4.077	>0.999
bh	36.5		–36.669	>0.999		–5.942	>0.999

al – lower *a* type of the chair, *bl* – lower *b* type of the chair, *ah* – higher *a* type of the chair, *bh* – higher *b* type of the chair, h8 – seat height, t4 – seat depth, b3 – seat width, F – popliteal height, D – buttock-popliteal distance, L – hip breadth

TABLE 4
SCHEEFE'S POST HOC TEST FOR VARIABLE F

Grade	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean value (cm)	34.809	37.236	38.400	40.603	42.232	43.679	45.327	45.520
1								
2	0.005867							
3	0.000000	0.353710						
4	0.000000	0.000000	0.009140					
5	0.000000	0.000000	0.000000	0.116672				
6	0.000000	0.000000	0.000000	0.000000	0.342995			
7	0.000000	0.000000	0.000000	0.000000	0.000003	0.147236		
8	0.000000	0.000000	0.000000	0.000000	0.000018	0.151463	0.999995	

(Figure 3). Such classification on lower and higher grade groups (but not of the users) is the milestone of the Croatian regulations regarding provision of the equipment for academic institutions. From a statistical point of view, this entirely meets the needs of both groups in that small-sized and large-sized furniture is available for the respective groups of users. However, according to the collected data, seat height for the group of smaller pupils should be $h8(l)=38^{+1}$ cm and for the group of taller $h8(h)=44^{+0.5}$ cm. This is so if the compliance of anthropometric dimensions of the measured sample is to be achieved. The results (Table 3) show height compliance between the chairs group *al* and smaller population, which is not the case with the higher group type *ah* and the pupils grade 5–8 due to the fact that this type is too high for its users.

TABLE 5
THE SUGGESTED NEW GROUPS OF CHAIRS AND ITS COMPARISON WITH THE STANDARD HRN ENV 1729–1:2003

New group seat height	New seat height measured (cm)	h8 (cm) HRN ENV 1729–1:2003	Size mark HRN ENV 1729–1:2003
1	34.8	36	4
2	38	36–41	4–5
3	41	41	5
4	45	45	6

Considering the EN 1729–1 standards applicable to primary schools, for the smaller group (mark size 4) h8=36 cm and for the taller group (mark size 6) h8=45 cm. The obtained values for anthropometric dimensions of F parameter would not fit smaller group and the pupils would be generally sitting on extremely small chairs.

Test results of D and t4. Test results of the seated upper leg length (D) and seat depth (t4) show that all furniture groups, with the exception of group *bl* (too shallow), were sufficiently deep and fitting. In connection with this result it must be noted, however, that only variables D and t4 were taken into consideration, with no account of other variables e.g. height and slope of the seat or reference points of the backrest for the low back. Further studies should focus on the relations between these variables because the data for appropriate depth of the seat vary significantly, relevant to the seat height, backrest slope and the slope reference point for specific anthropometric dimensions of users.

Test results of L and b3. Seat width of the studied chair groups complies with the analyzed hip breadth. Hence, it can be concluded that all chairs are of appropriate dimensions, except in the combination where taller pupils use chair type *bl*, which is too narrow for them.

Scheefe's post hoc test for variable F. Given significant difference of grade 1 from other grades, it comprises a separate group which should use smaller size mark (i.e. height) of furniture. By harmonization of the mean F variable, grade 1 can get a better fitting seat height of $h8_{(1)}$ = 34.8 cm. Grades 2 and 3 can be grouped together and get $h8_{(2,3)}$ = 38 cm. Grades 4 and 5 comprise group 3 where $h8_{(4,5)}$ = 41 cm. Grade 6 partly covers group 3 and partly goes into group 4 of heights, covered by grades 7 and 8. According to the results, h8 for group 4 would be $h8_{(7,8)}$ = 45 cm. Such data classification shows that the existing two height groups are not sufficient. If the appropriate standardized size mark 1–7 is to be attached to them, the proposed sizes 3 and 4 would comply with the standard and size marks 5 and 6, whereas the proposed groups 1 and 2 are incompliant and can be hardly attached to lower size marks. In case of the upper limit of variable F (+95.00% reliability interval) preference for grade 1 would be size mark 4, while grade 2 and 3 preferred a size between 4 and 5 in standards.

Testing of all grades (1–8). Testing of the variable F in every grade separately (1–8) gives a better picture of the required seat heights (Figure 4). According to the obtained values of the variable h8 for all chair groups (*al, bl, ah* and *bh*), none of the chairs is appropriate for any lower grade (1–4), except for the final values which are fitting for grades 2 and 3. Lower groups type *al* and *bl* are for grades 1, 2 and 3 too high, but low for grade 4 with respect to F. Groups *ah* and *bh* are too high for lower grades. In higher grades low chairs group cannot be used at all because of their markedly small size. Group *ah* fits only grade 6, but for grade 5 it is too high, or too small for grades 7 and 8. Group *bh* being too high does not fit any grade. Consequently, with respect to the variable F, lower furniture groups (*al* and *bl*) fit only grades 2 and 3. Higher furniture group *ah* fits only grade 6, whereas group *bh* is too high for everyone. A problem lies in the first grade, for which there isn't any adequate dimensioned height of the chair group. The sitting posture of the first grade pupils is improper, the feet are not at the floor and the shoulders are raised, as in the Figure 5. Therefore, reading and writing is aggravated.

In an ideal world, schools would be equipped with the most suitable equipment, regardless of cost. Designers, architects, engineers, doctors and other professionals involved in designing »optimal« and ergonomically appropriate school task chairs apply anthropometric dimensions at sitting (upper leg length, popliteal height and buttocks breadth). However, only a few researchers[5,29,34] have tried to tackle the issues of the pupils' school workplace design from other perspective e.g. from the stand-

Fig. 5. Inadequate and too high dimensioned school chairs and tables forced lower pupils to incorrect sitting posture during reading or writing tasks. Feet are not on the floor.

Fig. 6. Inadequate dimensioned school chairs and tables forced higher pupils to incorrect sitting posture during reading and listening. Backs, shoulders and a spine are bent.

point that human race is not created for prolonged inactivity in one and the same position, or that the static anthropometry is not of much use for designing the furniture used for dynamic processes of bodily movements and rotations during reading, writing, looking at the board or concentrating on the teacher[35]. The approach to »sitting problem« must take into account that sitting is, by human nature, rather dynamic than static activity. Standards are limited on only 2D geometric space, but the human postures have to be considered in 3D geometric space[36].

Irrespective of new theories that are still under consideration, present work takes into account the available methods frequently applied in designing of school task chairs or equipping primary school classrooms. The aim is to prove that many institutions in the chain (starting from designers, manufacturers, decision-makers in procurement of the equipment) neglect them by frequently failing to apply them. Comparison of the aforementioned parameters has shown that not even a small number of key parameters in design and finishing are respected by many, while one of the critical ones is compliance of anthropometric dimensions with dimensions of school chairs.

Although there were statistically significant difference in measured anthropometric variables between boys and girls, it was difficult to separate sex and ages in one class, especially because both genders always use the same type of the chairs, in the matched double desks. With the omitting of this, the study has confirmed the assumption that there is almost no segment of the studied population, which has used the chairs of appropriate dimensions. The result is incorrect sitting posture (Figure 5 and 6).

At first glimpse the results might seem satisfactory if we take into consideration higher and lower grades (1–4 and 5–8). However, some grade groups do not have appropriately high chair. The problem is with smaller users (grades 1 and 2) for whom the measured chairs are too high and cause dangling of feet (Figure 5), whereas 4 grade pupils, due to too low chairs already show improper posture. Higher grades face similar problem because grade 5 and partly grade 6 use too high chairs, while abrupt change occurs with grades 7 and 8 where chairs are suddenly too low. The problem aggravates with higher grades when all pupils from grades 5–8 change classrooms (a shift from class teaching to subject teaching), so that during one school day they use various height chairs if the adequate ones are not available. In one class the height differences of almost 20 to 30 cm in each classroom means that several height levels of chairs (and matching tables) should be available.

Conclusion

In summary, current study suggests a substantial mismatch between the pupils' dimensional variables, which are important for sitting, and dimensions of the task chairs in classrooms. These study findings are based only on the data from a convenience case in one region and school district (Zagreb). Although distribution pattern of anthropometric variability in primary school pupils (according to age) resembles that in other countries, growth pattern of the Croatian pupils shows some variations[27]. However, the Croatian children are among the tallest in Europe. Systematic anthropometric variations in gender and body dimensions may vary between the regions, which our study has not captured. These data must be included in future research and harmonized with international standards. Finally, our results are focused on three basic anthropometric variables for sitting positions, which are applied in static anthropometry. If sitting is defined as an »active working position«, our measuring system requires different approach and dynamic anthropometric values, including other (furniture and body) variables[36].

However, according to these results, having only two available chair sizes (irrespective of type) cannot suit all primary school children. On the basis of the study results we propose four height groups of chairs (Figure 7). We also recommend introduction of the compulsory biannual anthropometric measurements in all primary schools for provision of preliminary data that will help the teachers and state agencies equip classrooms with appropriately dimensioned furniture. A range of sizes must be available so as to allow each pupil choose the best suited one and, according to the changing anthropometric dimensions, to allow periodical change of chair size. Production of minimum four recommended furniture sizes is a decision of the Croatian furniture manufacturers as well as

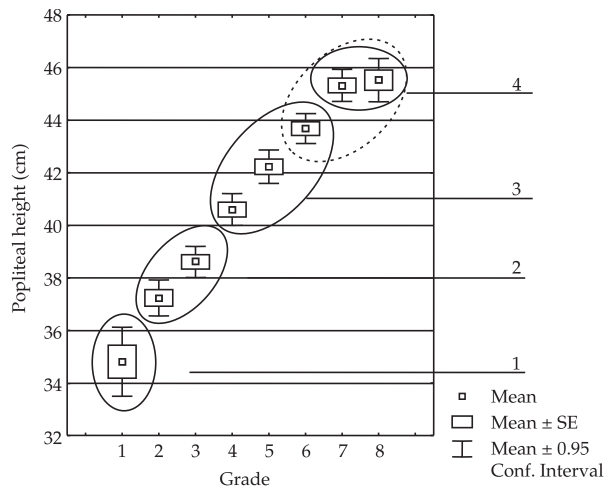

Fig. 7. The proposed four height groups of chairs.

of the government, Ministry of Science, Education and Sports and of school management and teaching staff equally. If government is not willing to replace traditionally designed two-sized furniture through state procurement of schools, the research results will not change. In addition to introducing different sizes or the adjustable chairs and the matching tables, a one-pupil desk must also be taken into consideration.

It is important that consideration is given to individual adjustment of furniture with regard to the user's age and dimensions. Health professionals at schools and the teachers must actively promote basic understanding of appropriate sitting position, of sitting behaviour and of correct usage of adjustable furniture (where available).

REFERENCES

1. PREBEG Ž, PREBEG Ž, Higijena i škola [in Croatian] (Školska knjiga, Zagreb, 1985). — 2. LINTON, SJ, HELLSING AL, HALME T, ÅKERSTEDT K, Appl Ergonomics, 25 (1994) 299. — 3. STORR-PAULSEN A, AAGAARD-HENSEN J, Appl Ergonomics, 25 (1994) 63. — 4. KNIGHT G, NOYES J, Ergonomics, 42 (1999) 747. — 5. BRIDGER RS, WHISTANCE RS, Posture and Postural Adaptation in the Workplace, Taylor & Francis, London, 1998, Available from: http://www.louisville.edu/speed/ergonomics/ency/ency_sample.html, accessed May 18, 2006. — 6. ATTINGER D, GASSER H, ILLI U, RIESEN S, SCHLUMPF U, SENN E, STÜSSI E, WECKERLE K, Sitzen als Belastung, Aspekte des Sitzens, Lehrunterlagen [in German] (PMSI Holdings Deuchland GmbH, Ismaning, München, 1993). — 7. DOMLJAN D, GRBAC I, BOGNER A, Wood Ind, 55 (2004) 77. — 8. TREVELYAN FC, LEGG SJ, Appl Ergonomics, 37 (2006) 45. — 9. PARCELLS C, STOMMEL M, HUBBARD RP, J of Adolesc Health, 24 (1999) 265. — 10. LEGG SJ, PAJO K, MARFELL-JONES M, SULLMAN M, Mismatch between classroom furniture dimensions and student anthropometric characteristic in three New Zealand secondary schools. In: Proceedings. (XVth Triennial Congress of the International Ergonomics Association, IEA, Seoul, Korea, 2003). — 11. JELAČIĆ D, MOTIK D, GRLADINOVIĆ T, GALAJDOVA V, Wood research, 48 (2003) 53. — 12. PANAGIOTOPOULOU G, CHRISTOULAS K, PAPANCKOLAOU A, MANDROUKAS K, Appl Ergonomics, 35 (2004) 121. — 13. VLAOVIĆ Z, Study of the office chairs comfort, [MS Thesis], [in Croatian], (University of Zagreb, Zagreb, 2005). — 14. DOMLJAN D, GRBAC I, Ergonomic principles relating to the design of school furniture. In: Proceedings. (30th International Conference on Furniture Industry Adjustment to European Standards, University of Zagreb, Faculty of Forestry, UFI-Paris, Zagreb, 2003). — 15. MANDAL AC, Appl Ergonomics 12 (1981) 19. — 16. ***, Interview with an employer in Ministry of Education and Sport, Republic of Croatia (Zagreb, 2000). — 17. ENV 1729–1:2001, Furniture; Chairs and Tables for educational institutions, Part 1, Functional dimensions (CEN/TC207, Brussels, 2001). — 18. HRN ENV 1729–1:2003, Furniture; Chairs and tables for educational institutions, Part 1, Functional dimensions. (Croatian Standards Institute, Zagreb, 2003). — 19. MOLENBROEK J-FM, KROON-RAMAEKERS YMT, SNIJDERS CJ, Ergonomics, 46 (2003) 681. — 20. PREBEG Ž, Krivulje centilne distribucije visine i težine školske djece i mladeži u Hrvatskoj [in Croatian] (University of Zagreb, Zagreb, 1988). — 21. NORRIS B, WILSON JR, Childata, the Handbook of Child Measurements and Capabilities – Data for Design Safety, Consumer safety unit (University of Nottingham, DTI, Nottingham, UK, 1995). — 22. MUFTIĆ O, VELJOVIĆ F, JURČEVIĆ-LULIĆ T, MILIČIĆ D, Osnovi ergonomije [in Croatian] (University of Sarajevo, Sarajevo, 2001). — 23. SMITH S, NORRIS B, Childata. Assessment of the Validity of Data (DTI, London, 2001). — 24. JELAČIĆ D, GREGER K, GRLADINOVIĆ T, Wood Ind, 53 (2002) 99. — 25. FINDAK V, METIKOŠ D, MRAKOVIĆ, M, NELJAK B, Napredak, 137 (1996) 28. — 26. MRAKOVIĆ M, FINDAK V, METIKOŠ D, NELJAK B, Napredak, 137 (1996) 279. — 27. PREBEG Ž, Variations in growth patterns of schoolchildren in Croatia over the last decade. In: ROBERTS DF, RUDAN P, ŠKARIĆ-JURIĆ T (Eds), Growth and Development in the Changing World (Anthropological library, Croatian Anthropology Society, Zagreb, 1997). — 28. ***, Interview with the Mrs. N. Jureša, PhD, dr med., president of the Department for the school medicine. (University of Zagreb, Medicine Faculty, Zagreb, 2004). — 29. HÄNNINEN O, KOSKELO R, Adjustable tables and chairs correct posture and lower muscle tension and pain in high school students, In: Proceedings. (XVth Triennial Congress of the International Ergonomics Association, IEA, Seoul, Korea, 2003). — 30. ***, No more sitting on the old school bench, BackCare, Talckback, spring 2002, Available from: http://www.backpain.org/pages/t_pages/tb-bench.php, accessed July 15, 2006. — 31. PANERO J, ZELNIK M, Human Dimension and Interior Space, A source book of design reference standards (Watson-Guptill Publications, New York, 1979). — 32. ŠOŠIĆ I, Primjenjena statistika [in Croatian] (Školska knjiga, Zagreb, 2004). — 33. STATSOFT INC, Electronic Statistics Textbook, StatSoft, Tulsa, OK, 2003, Available from: http://www.statsoft.com/textbook/stathome.html, accessed April 10, 2005. — 34. MANDAL AC, The prevention of back pain in school children. In: LUEDER R, NORO K (Eds), Hard Facts About Soft Machines: The Ergonomics of Seating (Taylor & Francis, London, 1994). — 35. CARDON GM, DE CLERCQ DL, GELDHOF EJ, VERSTRAETE S, DE BOURDEAUDHUIJ IM, Eur Spine J, 16 (2007) 125. — 36. MUFTIĆ O, Biomehanička ergonomija [in Croatian] (University of Zagreb, Zagreb, 2005). — 37. CARDON G, DE CLERCQ D, DE BOURDEAUDHUIJ, I, BREITHECKER D, Patient Educ Couns, 54 (2004) 133.

D. Domljan
Department for Furniture and Wood Product, Faculty of Forestry, University of Zagreb, Svetošimunska 25, 10002 Zagreb, Croatia
e-mail: domljan@sumfak.hr

DIZAJN ŠKOLSKOG NAMJEŠTAJA – ODNOS DIMENZIJA UČENIKA I STOLICA

SAŽETAK

Ova studija imala je za cilj ustanovljavanje odnosa antropometrijskih dimenzija učenika od 1. do 8. razreda osnovnih škola i dimenzija školskih stolica. Izvršena je procjena dviju dimenzija stolica, upotrebljavanih u svakodnevnoj nastavi, kako bi se ustanovilo da li zadovoljavaju prilagodbom i imaju li utjecaja na položaj sjedenja kod učenika. Istraživanje je provedeno na uzorku od 556 učenika iz tri osnovne škole u Zagrebu, Hrvatska i na dva tipa namještaja. Dimenzije školskih stolica uspoređivane su s tri antropometrijske varijable učenika. Deskriptivnom statistikom analizirane su sve varijable. Rezultati istraživanja pokazali su da namještaj odgovarajućih dimenzija nije dostupan većem broju učenika u Hrvatskoj. Sadašnja nabava školske opreme određena je s dvije veličine, što ne odgovara korisnicima. Za prihvaćanje školskih stolice u hrvatskim školama preporuča se podjela na četiri visine ili uvođenje stolica s individualnim podešavanjem. Osim toga, izuzetno se preporuča da škole uporno promiču odgovarajuće aktivno sjedenje učenika.