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MISMATCH BETWEEN THE ANTHROPOMETRIC PARAMETERS AND CLASSROOM FURNITURE IN THE SLOVAK PRIMARY SCHOOLS

Nadežda Langová – Sylvia Blašková – Jozef Gáborík – Denisa Lizoňová – Andrej Jurek

ABSTRACT

The aim of the study was to compare classroom furniture sizes in four primary schools with the anthropometric measurements of the Slovak school children in the region of Central Slovakia in order to evaluate the potential mismatch between them. Following the measure in their body dimensions, functional dimensions relating to the appropriate size, shape and ergonomic design of classroom furniture were evaluated. The measurements of 295 school children of four primary schools in Central Slovakia were carried out. The basic anthropometric measures such as stature, popliteal height, shoulder height, sitting, elbow height, sitting, thigh thickness, hip width were measured. Following the measured dimensions, the appropriateness of functional dimensions of the classroom furniture used in individual grades was evaluated. The seat height, seat to desk clearance, the seat width was evaluated. The seat to desk clearance resulted in proposing a formula for calculating the height of the storage shelf. Results indicated that seat height, which should be considered the starting point for the design of classroom furniture, the appropriate students' popliteal height was only in the case of 23% of the 6 year old pupils, the seat height was appropriate for 87.89% of 14 year old pupils. In the classrooms of the first and the second grade, according to the age of the school children, there is usually only one dimension of furniture used. Therefore, it does not meet the needs of all children.

Key words: classroom furniture, school children mismatch, anthropometry.

INTRODUCTION

Classroom furniture is a very special group of furniture, which must meet various dimensional and safety requirements. It is especially due to the target users, children, attending primary schools whose body is still developing, and the body measurements change rather quickly during this period. Therefore, this period is very important, nothing must be ignored and preventing the health problems at the older age must be ensured. When there is ignored anything at the time of body development it can result in various health problems and chronic pain by study BREZIN and ANTOV (2015).

Specific workplace for a student is a sitting position at the desk, designed for writing, reading and various other activities related to the educational process. In general, a chair and a desk are considered to be an interacting set. Due to the length of sitting time during classes, a quality chair is the basis for providing optimal performance in the workplace. Slovak

primary school children spend about a quarter of the day in a sitting position in the workplace. It is 5 hours on average and children must be fully concentrated on work for 45 minutes and the only opportunity to stretch their body is a 10-minute break. Considering the amount of time spent in the sitting position, furniture manufacturing industry must provide the classroom furniture supporting correct sitting posture. Comfortable sitting affects our feeling of comfort and ability to concentrate. The mismatch between school children and classroom furniture is likely to result in several negative effects, such as uncomfortable body posture, pain, and ultimately (ILIEV *et al.* 2019, DOMLJAN 2019, BRANOWSKI *et al.* 2020). Moreover, the teaching-learning process can be affected in negative way as well. Due to the situation, the most intensive interest in classroom furniture can be observed, particularly regarding the study and design of school furniture. Determining the standards dealing with classroom furniture can be considered a milestone. The furniture sizes are defined with the aim at accommodating school children with different anthropometric measurements (CASTELLUCCI *et al.* 2014, ALIBEGOVIĆ *et al*. 2020).

Quality and ergonomically balanced seating is especially important for students of the first grade at primary schools. According to a study of the State Institute of Public Health of the Slovak Republic from 2003, the biggest increase in the postural problems among children in the Slovak Republic occurs between the ages of 7 to 11. In the classrooms at the first grade in any country, the height children of the same age differ reaching varieties of 200 mm (CASTELLUCCI *et al.* 2010). This significant height difference must be taken into account when designing fixed or adjustable school desks and chairs.

Several scientific works are focused on the mismatch between classroom furniture sizes and anthropometric measurements of students in terms of national levels (DIANAT *et al.* 2013, FASULO *et al.* 2019, CASTELLUCCI *et al.* 2014, MÁCHOVÁ *et al*. 2019, LANGOVÁ *et al*. 2019). The results showed that there is a considerable mismatch between body measurements of the school children and the existing classroom furniture. The seat height, seat width and desktop height are the furniture sizes with a level of mismatch more than 52%. The levels of mismatch varied between the grades and between genders indicating the special requirements and possible difficulties. The assumption that children could use the most appropriate available size significantly improved the match indicating that the limited provision of one size per cluster of grades does not accommodate the variability of anthropometry even among children of the same age (PARCELLS *et al.* 1999). Fewer than 20% of students can find acceptable chair/desk combinations. Most students sit on chairs with seats that are too high or too deep and at desks that are too high. Even after controlling the body stature, girls are less likely to find fitting chairs (LEE *et al.* 2018). MOLENBROEK and RAMAEKERS (1996) stated that based on the anthropometric data, every country can design fitting furniture for school children. This would require to update measures from the relevant population (age 4–20 years) including at least 40 subjects from each age group and gender. Furthermore, the system was applied on Dutch, English, and German children (MOLENBROEK *et al*. 2003, PARCELLS *et al.* 1999)

The study (CARNEIRO *et al.* 2017) evaluates the relationship between student anthropometry and a height-adjustable school set. The results showed that the systems of present desks used to modify the height is compatible with the height of only half of the children. A drawer attached underneath the board of the can be the reason. To increase the degree of matching, new systems were developed for the desks and chairs using an algorithmic approach. The anthropometric data of small children are different than the elder ones. Hence, classroom furniture should be designed separately for them following ergonomic criteria and concentrating on users' comfort, adjustability, or possibility to choose set dimensions (YANTO *et al.* 2017, GOUVALI *et al*. 2006).

A considerable increase in stature (body height) of the population, both in adults and children, is the reason to carry out the research (HITKA *et al.* 2018a, HITKA *et al*. 2018b, RÉH *et al*. 2019, HITKA *et al*. 2020, BONENBERG *et al*. 2019). The aim of the study was to compare classroom furniture sizes in four primary schools with the anthropometric measurements of the Slovak school children in the region of Central Slovakia in order to evaluate the potential mismatch between them. A chair and a desk with no possibility of height adjustment is considered a school set. The fact that the Slovak Technical Standard STN EN 1729-1 (2017) defining the dimensions of classroom chairs and desks is available, but it does not deal with the set as a whole is important. Therefore, we would like to focus on designing the correct combination of the set as a whole. The obtained results seem to be relevant as they provide a scientific basis for the design and they are compatible with the anthropometric measurements of the studied population of users.

EXPERIMENTAL PART

Based on available data from the years 1976 to 2011, a database of existing anthropometric measurements of school children was created. The gathered data were from the years 1976, 1980, 1985, 2001, 2009 and 2011. The data from 1976 were based on the measurements performed in Slovakia in the 70s. Relevant data used in the research were associated with children aged 7 and 8 years. The data from 1980 and 1985 followed the measurements made during the Czechoslovak Spartakiads. The data useful in the research were about children aged 6, 7, 8, 13, 14 and 15. The data from 2001 and 2011 were provided by the Regional Public Health Authority of the Slovak Republic. It was a source of data on children aged 7, 8, 13, 14 and 15. The data from 2009 were based on the measurements of children in the Bratislava region and from there we used data on children aged 7 and 8 years.

Subsequently, in 2019, our own pilot measurements were performed, which show an increase in the stature of pupils compared to years 1976 to 2011. The pilot measurements were performed considering the ethical principles with the consent of students and their parents. Anthropometric measurements were performed in four different primary schools in the region of Central Slovakia. In total, 295 children were measured, out of which 158 were primary school children aged 6, 7, 8 and 137 were school children of the second grade 13, 14 and 15. The focus was given on these aged groups because of their most significant increase in height. Moreover, at the age of 6.7, children undergo an intensive learning process for the first time. At the age of 14, 15, their body dimensions are similar to those of adults. All data were gathered by the method of direct detection, measuring individual anthropometric characteristics of children. A detailed overview of the number of boys and girls and their age is given in Table 1.

Tab. 1 Sample distribution based on age, grade and gender.

Primary school	Age	Number of respondents in pilot measurements in 2019			The total number of respondents in the database in the years 1976–2019		
		Girls	Boys	Total	Girls	Boys	Total
I grade	6	20	18	38	80	78	158
	7	25	43	68	205	223	428
	8	26	26	52	206	206	412
II grade	13	12	23	35	132	143	275
	14	39	37	76	159	157	316
	15	5	21	26	125	141	266

The measurement of anthropometric characteristics was conducted according to the methodology specified in the standard STN EN ISO 7250-1 (2017). The following

anthropometric data (Fig.1) needs to be considered to estimate the most important furniture sizes:

a) **Stature (S)**: vertical distance between the floor and the top of the head and measured with the subject erect and looking straight ahead (Frankfort plane),
b) **Shoulder Height Sitting (ShH)**: vertical distance from subject seated surface to the acromion,
c) **Elbow Height Sitting (EH)**: taken with a 90° angle elbow flexion, as the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject seated surface,
d) **Popliteal Height (PH)**: measured with 90° knee flexion, as the vertical distance from the floor or footrest and the posterior surface of the knee (popliteal surface),
e) **Thigh Thickness (TT)**: the vertical distance from the highest uncompressed point of the thigh to the subject's seated surface,
f) **Hip Width (HW)**: the horizontal distance measured at the widest point of the hip in the sitting position,
g) **Knee Height (KH)** – vertical distance from floor to suprapatellar in anthropometric sitting posture.

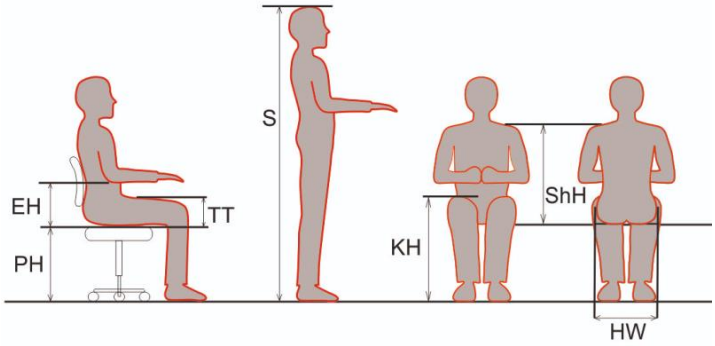


Fig. 1 Anthropometric characteristics used in this study.

In Fig. 2, the sizes of the classroom furniture of the four different schools measured are described.

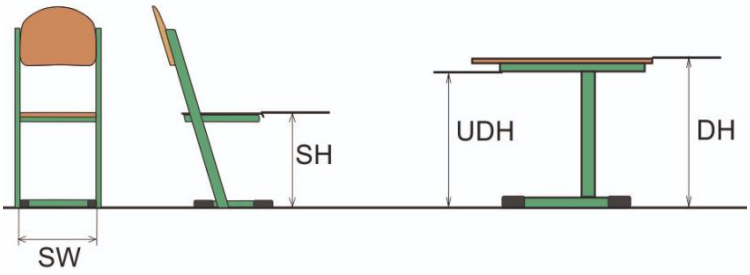


Fig. 2 Illustration of present school furniture and dimensions considered in this study. Desk height (DH): vertical distance from the floor to the tip of the front edge of the board of the desk; underneath desk height (UDH): vertical distance from floor to lowest point below the drawer; seat height (SH): vertical distance from floor to middle point of the front edge of the sitting surface; seat width (SW) horizontal distance between the right and left edges of the seat.

The seat height evaluated following the measured popliteal height and the desk height, or the distance between the seat and the upper surface of the desk top evaluated following the elbow height in seating were primary evaluated parameters. To evaluate the mismatch, the methodology according to CASTELLUCCI *et al.* (2010) and FIDELIS *et al*. (2020) was used. In the case of the two-way equations, three categories were defined: **high mismatch** is described as a lower limit of the criterion inequality higher than furniture size and a **low mismatch** is described as a higher limit of the inequality lower than the furniture size. A **match** is when

furniture size is between the lower and higher limits of the criterion inequality. For the one-way equations only 2 categories or levels were defined **match** and **mismatch** (FIDELIS *et al.* 2020). In the case of a high mismatch, school children will not be able to rest their feet on the floor, their legs will hang from the chair. This way the pressure on the inside of the thigh will increase and blood flow to the legs will be reduced and the legs start going numb.

Popliteal Height (PH) against Seat Height (SH)

The seat height (SH) is required to be balanced in respect to the popliteal height (PH) and enabling the knee to be flexed so that the lower legs shape a greatest of 30° edge with respect to the vertical. PH ought to be higher than the SH (PARCELLS *et al.* 1999). The lower leg constitutes a 5–30° point with respect to the vertical and furthermore the shin-thigh edge is in the vicinity of 95 and 120°. Typically, PH does not have an esteem higher than 4 cm or 88% of the PH. PH and SH are characterized when the seat stature is either >95% or <88% of the popliteal height and it is conceivable to build up a model for SH. Correction for shoe stature (SC) may naturally vary according to culture, fashion, and country. For this work, 2 cm correction for shoe stature is incorporated to the popliteal height (CASTELLUCCI e*t al.* 2010). This way, a match model is built up as follows (1):

$$(PH + SC) \cdot \cos 30° \leq SH \leq (PH + SC) \cdot \cos 5° \quad (1)$$

Sitting Elbow Height (SEH) against Desk Height (DH)

Various reviews (GARCIA-ACOSTA, LANGE-MORALES 2007, MOLENBROEK *et al.* 2003, CASTELLUCCI e*t al.* 2010) demonstrated that the elbow height is measured as the central point for the work area stature. As the load on the spine decreases, the arms are upheld on the desk and the desk height is liable to the shoulder flexion and shoulder snatching edge which is obtained by the fifth percentile. Thus, the work area stature ought to be 3–5 cm higher than the SEH. Subsequently, a match measure is set up with a changed condition (2) that acknowledges the SEH as the most minimal stature of DH and considering that the extraordinary height of DH ought not to be higher than 5 cm over the SEH.

$$SEH \leq DH \leq SEH + 5 \quad (2)$$

Hip width against seat width

To avoid discomfort and mobility restrictions, the SW should be higher than hip width (HW) (HELANDER 1997, CASTELLUCCI e*t al.* 2010). In this case the match criterion was one-way, when the:

$$SW > HW \quad (3)$$

Thigh thickness against seat to desk clearance

Seat to Desk Clearance (SDC): SDC is considered appropriate when it is higher than thigh thickness (TT) (MOLENBROEK *et al.* 2003). Also, CASTELLUCCI e*t al.* (2010), GARCIA-ACOSTA and LANGE-MORALES (2007) proposes that the SDC should be 2 cm higher than TT. The equation for this furniture dimension is:

$$DC > 2 + TT \quad (4)$$

Furniture Sizes in the Selected Schools

In the Slovak primary schools, there are seven different size groups of school desks and chairs for the first and the second grade. Chairs with yellow markings are used in the first grade of primary schools for students aged 6, 7 and 8. According to STN EN 1729-1 (2017), the height of the chair is 35 cm, the width of the chair is 32 cm and the height of the table is 59 cm with corresponding colour. These sizes are for children with a height in the range between 119–142 cm. At the second grade of primary schools, for the seventh, eighth and ninth year of study, i.e. for school children aged 13, 14 and 15, chairs with green markings are used. According to STN EN 1729-1, this colour designation corresponds to a seat height of 43 cm, a width chair of 36 cm and a desk height of 71 cm. These sizes are for school children with a height range from 146 to 176 cm.

Descriptive statistics was used to evaluate the data and the overview of the anthropometric characteristics of school children was provided. According to the principle of the restrictive measures, a properly designed piece of furniture should take into account the sizes associated with the dimensions of the users, at least 90 % of the population, it means those, with dimensions falling between the values of the 5th and 95th centile. Thus, the percentage of people, whom a usable space or piece of furniture will not be adjusted, will amount to 5 and 10 %, respectively (SMARDZEWSKY 2015).

RESULTS AND DISCUSSION

Confirmation of the hypothesis of an increase in the body stature of school children

The trend of increasing body stature in the case of boys and girls is shown in Fig. 3. The aim of the comparison was to determine the changes in the anthropometric characteristics of children during the observed period.

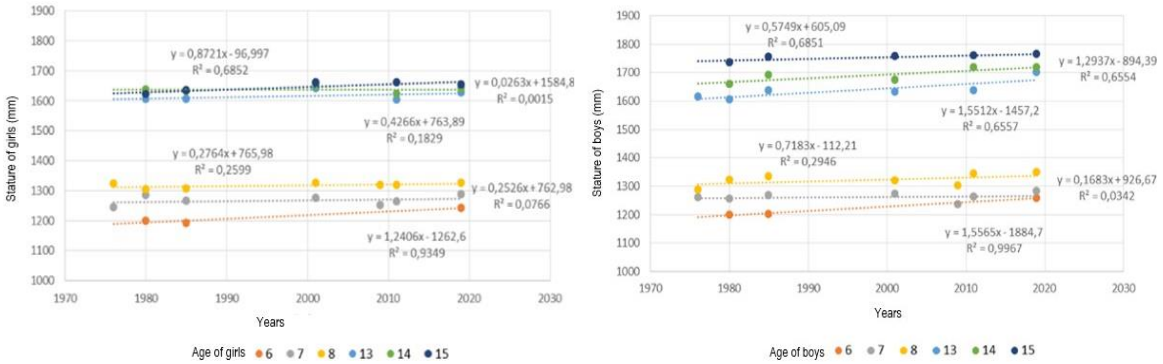


Fig. 3 Trend of increasing the stature of children according to the age and gender.

The average body stature of girls at the age of 6 increased by 4.29 cm, at the age of 7 years by 4.13 cm, at the age of 8 years by 0.06 cm, at the age of 13 years by 2.15 cm, at the age of 14 years by 0.43 cm and at the age of 15 years by 3.09 cm. The average body stature of boys aged 6 years increased by 5.92 cm, at age 7 years by 2.23 cm, at age 8 years by 6.23 cm, at age 13 years by 8.62 cm, at age 14 years by 5.8 cm and at the age of 15 years by 0.93 cm.

Comparing the increments of stature values, it was found out that the biggest difference in boys was at the age of 13 with an increase by up to 8.62 cm on average. Comparing the increments of body stature values in the case of girls, we found out that the biggest increase compared to the past occurred at the age of 6 years, specifically by 4.29 cm. Except for the age group of 7 years, there was an increases in body stature greater in boys than in girls. At some ages, the differences are smaller comparing to others, but the results show that there has been a clear increase in stature over the last 40 years.

Anthropometric Measurements of School children in the Selected Schools

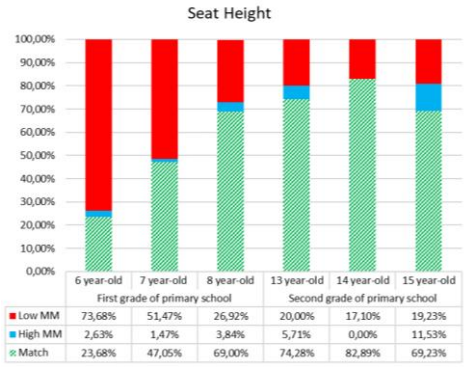
Children in lower grades are usually smaller than school children in the second grade. Therefore, there is not recommended to design the same furniture set for both grades of the primary school. The size of classroom furniture is divided into 7 groups in STN EN 1729-1. The eighth group marked 0 is intended for children in kindergarten. It is important to describe both groups of students in terms of anthropometry. These descriptions are given in Table 2.

Tab. 2 Anthropometric data of students (cm).

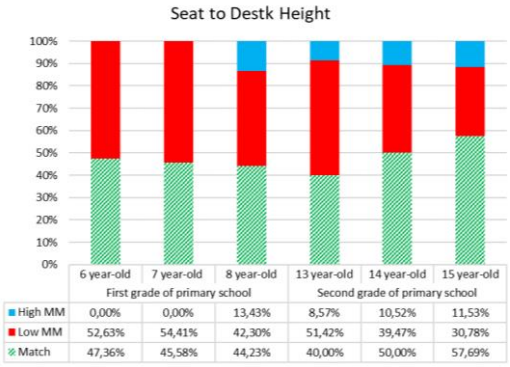
Age/gender/n	Descriptive statistics	Stature (cm)	Shoulder height, sitting (cm)	Elbow height, sitting (cm)	Knee height, sitting (cm)	Popliteal height, sitting (cm)
6 year old girls n=20	5th	116.03	41.04	15.31	36.36	30.39
	50th	124.55	43.55	18.80	40.45	33.00
	95th	132.03	47.82	22.53	43.00	35.35
	mean	124.31	43.94	18.76	40.05	33.02
	SD	5.38	2.38	3.09	2.16	1.79
6 year old boys n=18	5th	120.28	41.53	15.71	38.41	28.31
	50th	126.20	43.75	18.85	40.9	33.8
	95th	131.44	47.175	21.84	43.46	37.2
	mean	125.81	44.08	18.99	40.79	33.54
	SD	3.796	2.136	2.092	1.694	3.352
7 year old girls n=20	5th	121.50	41.80	15.58	38.42	32.36
	50th	128.50	45.10	18.90	42.10	35.20
	95th	135.00	50.50	23.68	45.26	36.66
	mean	128.69	45.21	19.26	42.09	34,74
	SD	5.46	2.78	2.44	2.10	1.61
7 year old boys n=18	5th	118.81	40.85	16.11	38.18	29.65
	50th	127.80	44.30	19.00	41.90	34.20
	95th	138.26	48.88	21.99	45.46	37.88
	mean	128.38	44.35	18.82	41,70	34.16
	SD	5.54	2.34	1.95	3.20	2.55
8 year old girls n=20	5th	123.1	41.4	17.225	39.45	31.75
	50th	132.3	45.8	20.10	43.9	35.3
	95th	144.02	49.965	24.095	48.425	40.82
	mean	132.52	45.38	19.95	43.87	35.76
	SD	6.147	2.572	2.596	3.035	3.056
8 year old boys n=18	5th	126.3	43.125	16.55	40.025	32.8
	50th	133.9	46.5	19,6	44.1	35.8
	95th	147.78	51.535	25.185	47.895	38.07
	mean	134.93	46.28	20.25	44.10	35.65
	SD	6.635	2.582	3.318	2.700	1.745
13 year old girls n=20	5th	152.275	53.24	20.685	49.655	39.495
	50th	165.00	58.9	24.85	53.25	43.8
	95th	167.45	62.32	27.53	56.925	46.105
	mean	162.71	58.33	24.58	53.05	43.05
	SD	5.402	3.097	2.490	2.495	2.516
13 year old boys n=18	5th	160.55	52.31	20.4	52.78	41.66
	50th	169.5	57.2	22.3	56.5	45.4
	95th	180.35	62.63	28.31	61.83	50.83
	mean	170.14	57.38	22.90	56.91	45.85
	SD	7.668	3.254	3.073	3.173	4.056
14 year old girls n=20	5th	151.75	54.7	20.91	48.34	39.44
	50th	165.00	58.5	24.4	53.9	43.8
	95th	172.7	62.66	29.66	57.69	47.83
	mean	164.09	58.32	24.75	53.42	43.49
	SD	7.022	2.979	2.832	3.162	2.496
14 year old boys n=18	5th	160.4	52.48	18.76	52.46	43.08
	50th	172.00	59.3	22.7	57.6	46.3
	95th	185.00	67.3	28.56	60.72	49.98
	mean	171.74	58.75	23.04	57.30	45.90
	SD	7.509	4.555	2.943	2.526	2.907
15 year old girls n=20	5th	160.8	55.18	21.76	52.66	40.34
	50th	162.5	60.9	27.5	54.5	42.7
	95th	173.00	75.14	27.8	57.5	47.04
	mean	165.30	63.18	26.14	54.76	43.24
	SD	5.085	8.074	2.879	1.899	2.658
15 year old boys n=18	5th	163.00	52.6	19.1	51.4	41.7
	50th	175.00	61.1	24.5	58.9	46.8
	95th	187.5	64.1	29.7	63.6	52.3
	mean	176.48	56.47	24.40	58.16	46.80
	SD	8.581	20.731	3.569	4.706	3.933

Mismatch between anthropometric data and classroom furniture

The percentage of school children necessary for evaluating the mismatch level is given in Fig. 4. The evaluation of the seat height is in Fig. 4a, and seat to desk height according to the age of the school children is in Fig. 4b.



	6 year-old	7 year-old	8 year-old	13 year-old	14 year-old	15 year-old
	First grade of primary school			Second grade of primary school		
Low MM	73,68%	51,47%	26,92%	20,00%	17,10%	19,23%
High MM	2,63%	1,47%	3,84%	5,71%	0,00%	11,53%
Match	23,68%	47,05%	69,00%	74,28%	82,89%	69,23%



	6 year-old	7 year-old	8 year-old	13 year-old	14 year-old	15 year-old
	First grade of primary school			Second grade of primary school		
High MM	0,00%	0,00%	13,43%	8,57%	10,52%	11,53%
Low MM	52,63%	54,41%	42,30%	51,42%	39,47%	30,78%
Match	47,36%	45,58%	44,23%	40,00%	50,00%	57,69%

a) **b)**

Fig. 4 Percentages of school children by match/mismatch level for evaluating the seat height and seat to desk height.

Seat Height:

The seat height is the basic size affecting the size of the desk, so it is evaluated as the first one. Following the measured value of Popliteal Height (PH) and the equation (1) for determining the height limit of the chair, we found out that when studying 158 primary school children, the seat height of 35 cm has a match of only 48.73% children, 2.53 % used a higher seat (High mismatch) and 48.73 % used a seat that was too low (Low mismatch). In the first grade, the seat height was appropriate for 52.11% of girls, 2.81% of girls used a higher seat and 45.07% of girls used a seat that was too low. The seat height was appropriate for 45.97% of boys, 2.29% of boys used a higher seat and 51.72% of boys used a seat that was too low.

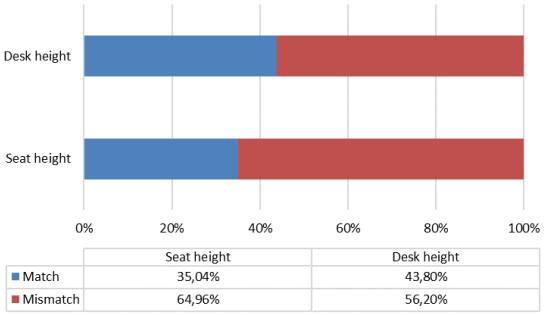
A total of 137 (56 girls and 81 boys) second grade children said the seat height of 43 cm was appropriate for 76.64% children, 5.10 % used a higher seat (High mismatch) and 18.24 % used a seat that was too low (Low mismatch). In the second grade, the seat height was appropriate for 67.85% of girls, and 32.14% of girls used a seat that was too low. The seat height was appropriate for 82.71% of boys, 8.64% of boys used a higher seat and 8.64% of boys used a seat that was too low.

Seat to desk height:

In terms of evaluating the seat to desk height, we observed that in the first grade, the seat to desk height is optimal for 45.56% of students, for 4.43% of students the height was too high (High MM) and for 47.46% of students is too low (Low MM). In the first degree, this assessment was almost identical in the case of girls as well as boys. The girls achieved a seat to desk height match rating for 47.88% of them, it was too low for 49.29% and too high for 2.81% of girls. In the seat to desk height evaluation, boys achieved a match for 43.67% of them, it was too low for 50.57% and too high for 5.76% of boys. In terms of seat to desk height evaluation, it was observed that in the second grade, the seat to desk height was optimal for 48.90% of students, for 10.22% of students the height was too high (High MM) and for 40.87% of students was too low (Low MM). Girls achieved a seat to desk height match rating for 62.50% of them, it was too high for 10.71% and too low for 26.78% of girls.

Boys achieved a seat to desk height match rating for 39.50% of them, it was too high for 9.87% and too low for 51.61% of boys.

Mentioned results were compared to the personal evaluation of children at the second grade of the primary school aged 13-15 years, children spend 6 hours sitting at an average. Following the questionnaire, it was found out that, in most cases, boys aged were not satisfied with the height of the chair or desk. The height of the backrest was sufficient for them, they had enough leg room and a sufficiently large desk top. For boys aged 14 and 15 the seat height and desk did not suit them. The backrest height, the leg room and the height desk top fit them. In most cases, girls aged 13 sat on the chair for 6 hours a day and the height of chairs and desk met tier requirements. The backrest height, the leg room and the height desk top fit them. For girls aged 14 and 15 the seat height and desk did not fit them. Fig. 6. shows a personal evaluation of the seat height and desk height of all students in the second grade.

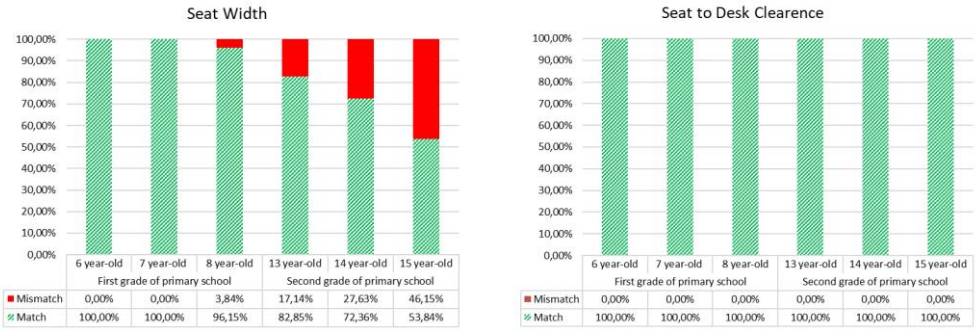


	Seat height	Desk height
Match	35,04%	43,80%
Mismatch	64,96%	56,20%

Fig. 6 Personal evaluation of seat and desk height by children aged 13–15.

Seat width and seat to desk clearence

The evaluation of the seat width and the seat to desk clearance is shown in Fig. 7.



	6 year-old	7 year-old	8 year-old	13 year-old	14 year-old	15 year-old
	First grade of primary school			Second grade of primary school		
Mismatch	0,00%	0,00%	3,84%	17,14%	27,63%	46,15%
Match	100,00%	100,00%	96,15%	82,85%	72,36%	53,84%

	6 year-old	7 year-old	8 year-old	13 year-old	14 year-old	15 year-old
	First grade of primary school			Second grade of primary school		
Mismatch	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Match	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Fig. 7 Percentage of children by match/mismatch level for evaluation seat width (a) and seat to desk clearance.

The seat width fit 96.15% of children in the first grade, while at the age of 6 and 7 it was appropriate for 100% of children. At the age of 8, in the first grade, the width of the chair fit 100% of girls and 92.30% of boys. In the second grade, the width of the chair was appropriate for 70.07% of students, of which 66.07% are girls and 72.83% are boys.

As the construction of the desk consists only of the supporting part and the worktop of the desk, the seat to desk clearance will fit all children in the first and the second grade. School children have enough leg room and space for the movement on a chair. Following the dimensions of the desk, chair, and thigh thickness (TT) and the requirement (Eqv. 3), the equation 4 to calculate the position of the storage shelf was derived. The position of the storage shelf is not specified in the standard STN EN 1729-1 or in regulation of the Slovak Republic No. 527/2017. Therefore, based on the anthropometric characteristics of the school

children and the construction dimensions of the furniture set, the calculation of the height of the storage shelf was proposed using the equation 5.

$$p_1 = h_1 - (TT + 2 + h_8) \quad (5)$$

where: p_1 – the height of the storage shelf, i.e. the distance between the upper surface of the desk top and the lower surface of the storage shelf (cm),
h_1 – desk height (cm),
TT – thigh thickness (cm),
h_8 – seat height (cm).

CONCLUSION

The aim of this paper was to evaluate the relationship between the classroom furniture and school children anthropometric characteristics studying the sample set consisting of 295 school children from primary schools in Central Slovakia. Based on our pilot measurement, we found an increase in the stature of pupils compared to the period 1976 to 2011. This increase was specific in the case of each age and gender. The major increase in stature was recorded in the case of boys aged 13, by 8.62 cm. The biggest increase in height in girls was recorded at the age of 6, specifically by 4.29 cm.

Measurements and calculations showed that the greatest mismatch at seat height was found in the first grade children, aged 6 to 8 years. In this case, their seat was too low. Also, evaluating a seat desk height showed that the furniture set used was small for children in the first and the second grade of primary school. This mismatch causes pain in the shoulders and neck as well as discomfort in the knees and inner thighs. Any pain or discomfort reduces the quality of sitting and concentration. The seat width is satisfactory. There was an increase in the percentage of children in the second grade, aged 15, whose seat width is inconvenient.

When evaluating the distances between the desktop and the seat height, which is evaluated based on the thigh thickness, there can be seen positive reaction in all students. This is justified by the fact that school desks do not have storage space. Therefore, the equation to calculate the height of the storage shelf was proposed.

While according to the STN EN, up to 7 different sets can be used. It is necessary to follow the recommendation that there should be at least three different furniture size in the classrooms. Of course, the ideal situation could be when the children stature was marked on the desk and chairs, so that the teacher would be able to assign a table and a chair of the desired height to the student according to this basic anthropometric characteristic.

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AUTHORS'ADDRESS

Ing. Nadežda Langová, PhD.
Ing. Silvia Blašková, PhD.
Assoc. prof. Ing. Jozef Gáborík, CSc.
Ing. Denisa Lizoňová, ArtD.
Ing. Andrej Jurek
Technical University in Zvolen
Faculty of Wood Sciences and Technology
Department of Furniture and Wood Products
T.G. Masaryka 24
960 01 Zvolen
Slovakia
langova@tuzvo.sk
gaborik@tuzvo.sk