

## DESIGNING ERGONOMIC POST-COVID-19 SCHOOL FURNITURE

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### ABSTRACT

Inappropriately designed classroom furniture that does not take children's anthropometric measurements into account has a negative effect on children's musculoskeletal systems. In this study, which kept Covid-19 pandemic policies in mind, students' static anthropometric dimensions were measured and their descriptive statistics calculated, using mean, standard deviation, percentiles, and statistical tests, including the t-test and one-way ANOVA. A new design for ergonomically oriented classroom furniture for primary school students is proposed that takes into consideration the measured anthropometric dimensions for students' safety, health, and well-being, and for post-Covid-19 policies. Given the results of the study, school managements must consider the gender and age of students, and take post-Covid-19 policies/protocols into account when procuring classroom furniture.

### OPSOMMING

Klaskamermeubels wat nie die antropometriese metings vir kinders in ag neem nie, het 'n negatiewe uitwerking op die muskuloskeletale stelsels van kinders. In die studie, wat die Covid-19 pandemiebeleid in ag geneem het, is studente se statiese antropometriese dimensies gemeet en beskrywende statistieke van kinders bereken; die gemiddelde, standaard afwykings, persentiele en statistiese toetse insluitend t-toets en eenrigting-ANOVA. 'n Nuwe ontwerp van ergonomies-georiënteerde klaskamermeubels vir laerskoolleerlinge word voorgestel wat die gemete antropometriese dimensies van die studente se veiligheid, gesondheid, en welstand en vir die opstel van na-Covid-19 beleide in ag neem. Die resultate van die studie dui daarop dat die skoolbestuur die geslag en ouderdom van studente, en na-Covid-19 beleid/protokolle in ag moet neem wanneer klaskamermeubels verkryg word.

## 1 INTRODUCTION

Chairs are known to have been in use during the Early Dynastic Period (c. 2900-2350 BCE), and have certainly been used since ancient times. Sometimes they were covered with cloth or leather, and sometimes they were made of carved wood, especially by the Egyptians. In ancient times chairs, desks, and tables were much lower than they are today – for example, seats were only 25 cm in height.

Furniture designs changed a lot over the centuries, whereas chair/seat and table designs changed very little. Chairs were depicted with a low seat such as can be seen with the Egyptian Pharaohs' stools [1]. Ergonomics and anthropometry have been combined to make them adjustable and so accommodate a wider range of people, and to develop new forms of furniture such as task-related office tables and chairs [2]. Furniture is an essential element if people are to be able to work comfortably. Therefore, furniture designs have been changed to consider ergonomics and anthropometric data [3,4].

School furniture is a key factor for the adoption of proper posture and consequently for students' greater productivity. The high level of mismatch between students on the one hand, who vary greatly in gender, nationality, body structure, age, physical activity, and nutrition, and school furniture on the other hand is being associated with low back pain in adolescents.

In the post-Covid-19 period, necessary changes have been made to the spacing between people – i.e., social distancing. This has been achieved by using unused spaces, by adding new elements to existing furniture and to necessary spaces, or by buying new furniture that has transparent shields, to prevent the transmission of Covid-19.

Many researchers have investigated the design of chairs and desks, and their combinations in the work place, such as computer workstations [5,6,7,8,9]; and a few have worked on ergonomic-oriented classrooms' furniture designs [10,11,12,13,14,15,16,17, 18, 19]. In the literature, a few studies show a mismatch between the anthropometrics characteristics and the dimensions of classroom furniture, whereas very few studies investigate the topic 'mismatch' under post-Covid-19 policies and protocols. However, this mismatch affects the learning process, and can produce musculoskeletal disorders.

### **1.1 Aim of study**

Because of the Covid-19 pandemic, schools were closed during the spring semester of 2019-2020 and the autumn semester of 2020-2021, affecting many students. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Covid-19 pandemic affected the education of around 1.6 billion students in 190 countries – i.e., 94 per cent of the world's children [20].

Schools in Turkey and elsewhere have ergonomically oriented classroom furniture problems – i.e., mismatched classroom furniture. The mismatch between students and school furniture is likely to result in a number of negative effects, such as uncomfortable body posture and pain; and ultimately it also affects the learning process. One of the main reasons for the mismatching of classroom furniture is over-crowded classes because of high population growth. Since the population of Turkey is increasing, it increases the country's student population. Other than this factor, schools' budget constraints and lack of educational funding are the other economic factors that prevent school management from changing the schools' furniture and buying suitable school desks and chairs that take account of the ergonomic criteria of students – i.e., students' anthropometric measurements.

The main goal of this study was to recommend and to advise school managers on ergonomically oriented systems that are based on a student health framework. The study showed that there is a big mismatch between students and their furniture (desks and seating benches), which meant that the furniture was not comfortable, was over-sized, or, in some cases, was smaller than required. Classes were crowded, and they complained about their pains/aches – an indication of the onset of ergonomically related diseases. Therefore, the aim of this study was to design new post-Covid-19 ergonomically centred classroom furniture by taking students' anthropometric data into consideration.

### **1.2 Previous studies of school furniture**

There are few studies in the literature on the ergonomic design of school furniture; and they are focused on students' anthropometry. To design school furniture, it is important to get the necessary correct anthropometric measurements of students to make ergonomic designs.

Many studies have shown that children are seated for long periods in classrooms [9, 21, 22, 23] and that this causes bone and muscle pains, such as low back pain [24], back pain [25], and other problems from prolonged sitting [8, 9, 26, 27, 28, 29, 30, 31, 32, 33, 34]. There is no study in the literature of ergonomic classroom furniture that considers post-Covid-19 policies and protocols.

## **2 MATERIAL AND METHODS**

The Covid-19 crisis has forced most education systems to find alternatives to face-to-face teaching and learning. Many education systems have moved their activities online to allow instruction to continue despite school closures.

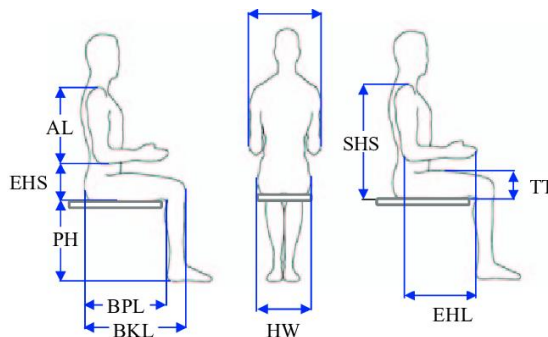
During the anthropometric measurements, it is important to follow a standard procedure in which the measurements are collected from the right side of the subjects while they are sitting in a standard position, without shoes and wearing light clothes. After collecting the measurements, it is important to check the data by using observations of the mean, the minimum and maximum values, and the calculation of the different measurements. To determine the dimensions and characteristics of different types of school furniture, seat height should be the starting point, and the designs need to be based on a bottom-top approach.

A standard ISO procedure was followed while collecting the anthropometric measurements; and to determine the dimensions and characteristics of different types of school furniture, a bottom-top approach was used in this study. In the autumn semester of the 2020-2021 academic year, Turkish students' anthropometric measurements that were needed (as guided by ISO 7250 [1996]) to design chairs, desks, tables, and seating benches – i.e., school furniture – were taken according to the relevant ISO and EN standards (ISO 5970-1979 and EN1729). The number of students thus measured are presented in Table 1.

**Table 1: Number of investigated students**

Student Numbers	Boys	Girls	Total	Ratio
1st grade	88	86	174	12.54
2nd grade	77	72	149	10.73
3rd grade	79	77	156	11.24
4th grade	89	87	176	12.68
5th grade	88	81	169	12.18
6th grade	91	93	184	13.26
7th grade	97	89	186	13.40
8th grade	98	96	194	13.98
Total:	707	681	1,388	100.00

Activities performed in the classroom and children's sitting postures are influenced by their anthropometric measurements such as popliteal height (PH), elbow height sitting (EHS), buttock-popliteal length (BPL), buttock-knee length (BKL), hip width (HW), shoulder height sitting (SHS), elbow breadth sitting (EBS), thigh thickness (TT), arm length (AL), and elbow-hand length (EHL), as shown in Figure 1.



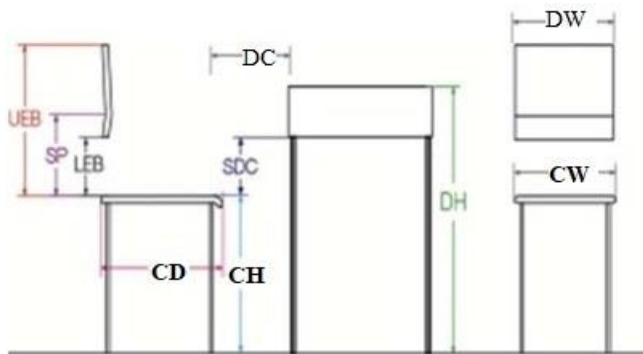
**Figure 1: Students' anthropometric measurements**

The students' anthropometric measurements used in the study are listed below:

- Shoulder height sitting (SHS): vertical distance from subject's seated surface to the acromion.
- Elbow height sitting (EHS): taken with a 90°-angle elbow flexion, as the vertical distance from the bottom of the tip of the elbow (olecranon) to the subject's seated surface.
- 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).
- 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.
- Buttock-popliteal length (BPL): taken with a 90°-angle knee flexion as the horizontal distance from the posterior surface of the buttock to the popliteal surface.
- Buttock-knee length (BKL): taken with a 90°-angle knee flexion as the horizontal distance from the posterior surface of the buttock to the front of the kneecap.

- 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).
- Subscapular height (SUH): the vertical distance from the lowest point (inferior angle) of the scapula to the subject's seated surface.
- Weight (W): Body weight.
- Sitting height (SH): the vertical distance between the ground and the sitting object's surface.
- Eye height (EH): the vertical distance between the sitting surface and the eyes.
- Elbow height (ELH): the vertical distance between the seated surface and the tip of the elbow.
- Shoulder height (SH): the vertical distance between the sitting surface and the shoulder.
- Arm length (AL): the distance between the elbow height and the shoulder.
- Elbow-elbow distance (ED): the horizontal distance between two acromions.
- Elbow-hand length (EHL): the horizontal distance between the elbow and the hand.
- Shoulder width (SW): the distance between the shoulders.
- Buttock width (BW): the distance between the outer edges of the the buttocks.
- Elbow breadth sitting (EBS): the horizontal distance between the elbows.
- Knee height (sitting) (KH): the vertical distance between the knees (in a sitting position).
- Sitting height (SHT): the vertical distance between the sitting position and the floor.
- Eye height (sitting position) (EH): the vertical distance between the eye and the sitting surface.
- Hip breadth distance (HBD): the distance between the right and left sides of the pelvis.
- Knee to knee breadth distance (KKD): the distance between the right and left sides of the knees.

In the study, the measurements of the school furniture – which included width of chair (CW), width of desk (DW), height of chair (CH), height of desk (DH), chair depth (CD), and chair to desk clearance (SDC) – were calculated while taking into consideration the anthropometric measurements of the Turkish students. They are presented in Figure 2, and listed below.



**Figure 2: Furniture dimensions used in the study**

- Chair height (CH): the vertical distance from the floor to the middle point of the front edge of the chair.
- Chair depth (CD): the distance from the back to the front of the sitting surface.
- Chair width (CW): the horizontal distance between the lateral edges of the chair.
- Upper edge of backrest (UEB): the vertical distance between the middle points of the upper edge of the backrest and the top of the chair.
- Desk height (DH): the vertical distance from the floor to the top of the front edge of the chair.
- Desk width (DW): the horizontal distance between the lateral edges of the desk.
- Seat to desk clearance (SDC): the vertical distance from the middle point of the front edge of the chair to the lowest structure point below the chair.
- Distance between desk and chairs (DC): the horizontal distance between the chair and the desk.

The weight and height measurements of the Turkish school students are presented in Table 2 and Table 3. All of the other related anthropometric measurements of students were also taken. The body dimensions of each student were obtained to make the necessary calculations and to design the school furniture in the autumn semester of the 2020-2021 academic year.

**Table 2: Students' weight measurements (kg)**

Class	Total student numbers	Average (kg)	Standard deviation ( $\pm$ )	Minimum	Maximum
1st grade	174	25.72	2.83	17.8	35.3
2nd grade	149	27.34	5.08	17.2	44.1
3rd grade	156	32.51	6.41	22.5	58.8
4th grade	176	35.84	7.39	23.1	60.8
5th grade	169	42.91	12.27	25.7	84.3
6th grade	184	45.38	12.15	26.9	88.6
7th grade	186	50.92	12.27	26.2	89.9
8th grade	194	56.86	12.92	32.6	86.7

**Table 3: Students' height measurements (cm)**

Class	Total student numbers	Average (cm)	Standard deviation ( $\pm$ )	Minimum	Maximum
1st grade	174	121.42	5.43	103	139
2nd grade	149	129.17	6.09	118	146
3rd grade	156	133.19	6.83	119	169
4th grade	176	142.81	7.38	123	171
5th grade	169	144.73	8.92	126	175
6th grade	184	149.28	8.83	127	177
7th grade	186	157.73	9.13	131	179
8th grade	194	162.18	9.95	139	184

Students' seating benches width measurements in one of the Turkish school are presented in Table 4.

**Table 4: Students' seating bench width measurements (cm)**

Class	Total student numbers	Average (cm)	Standard deviation( $\pm$ )	Minimum	Maximum
1st grade	174	24.96	2.36	21	32
2nd grade	149	25.73	2.24	22	33
3rd grade	156	26.04	3.45	23	33
4th grade	176	28.76	3.82	23	33
5th grade	169	28.98	3.41	23	36
6th grade	184	29.87	3.83	23	36
7th grade	186	31.86	4.01	23	39
8th grade	194	32.74	3.94	25	48

## 2.1 Analysis used in the study

The Turkish school students' descriptive statistics (mean, standard deviation, and key percentiles [5, 50, and 95 percentiles]; comparison of dimensions regarding gender) were calculated according to the anthropometric measurements required by the relevant ISO and EN standards. Students' t-tests and one-way ANOVAs were used to compare the means. In this study Turkey's one of the school's students ergonomic classroom furniture design considering post-Covid-19 policies and protocols is performed.

## 3 RESULTS AND DISCUSSION

The Covid-19 outbreak was experienced all over the world, starting in early 2020. Because of the pandemic, around 95 per cent of students around the world were temporarily out of school, and its impact has been troubling for all students. Governments had to continue their educational programmes by using distance-learning methods via television, radio, and the internet.

In this study, the anthropometric data of students in one of Turkey's primary schools were measured in the autumn semester of 2020-2021, using the relevant related ISO and EN standards and taking post-Covid-19 policies/protocols into consideration. The students' anthropometric measurements and the related calculations of the descriptive statistics (standard deviation, mean, and key percentiles: 5, 50, and 95 percentiles) were undertaken, and, from those calculations, the dimensions of Turkish ergonomically-centered classroom furniture (desks and chairs), considering the post-Covid-19 policies and protocols, are proposed in Table 8.

When students' t-test results were examined for the two genders (males and females), it was observed that there was a significant difference between the measurements – i.e., weight, elbow height, elbow height (sitting), knee height (sitting), sitting height, abdominal depth, arm length, shoulder height, eye height, forearm length, elbow-elbow distance, forearm-forearm distance, shoulder width, buttock width, hip breadth distance, eye height (sitting), chest depth, buttock-knee length, popliteal height, thigh clearance distance, buttock-popliteal length, knee-to-knee breadth distance, upper arm length. The study showed that there were significant differences between the students' gender-related anthropometric data for most of the dimensions and the key percentiles.

When examining the Anova table, it could be seen that there was a meaningful difference in all of the physical characteristics among students in different grades. (The test statistic p was lower than 0.05, making the difference meaningful.)

### 3.1 Comparison of existing seating bench dimensions and the students' anthropometric measurements

#### 3.1.1 Existing students' sitting width to seating bench width relationship

The students' seating bench width measurements in one of the Turkish's schools was calculated to be 27.86 cm, and the students' average sitting width was calculated to be 28.97 cm (the standard deviation was  $\pm 5.38$ ).

Table 5: One-sample test: Sitting width – T test chart

	Test value = 27.86 cm			
	t	df	Sig. (2-tailed)	Average difference
Sitting width	4.358	1,388	0.000	1.1317

As a result of the calculations shown in Table 5, the average seating bench width in all of the examined classes was calculated to be 27.86 cm. When we compared the calculated value with the students' sitting width, the sig. value was calculated to be less than 0.05. In the T-test chart, Table 5, the p-value was calculated to be 0.000 – that is, less than 0.05. There was a difference between the averages. When we compared the averages, we concluded that the students' sitting width dimension (in the specific Turkish school) was wider than the seating bench width. Therefore, we could conclude that the seating bench width was too small for the students.

### 3.1.2 Existing knee height to seating bench height relationship

As a result of the calculations, the average seating bench height of all the grades that were examined was calculated to be 41.38 cm. The average knee height of all of the students in the Turkish school was calculated to be 38.94 cm (standard deviation  $\pm 3.85$ ). When we compared the calculated value with the students' knee heights, the Sig. value was calculated to be less than 0.05. In the T-test chart, Table 6, the p-value was calculated to be 0.000, which is less than 0.05. There was a difference between the averages: when we compared them, we concluded that the students' knee height was shorter than the seating bench height, and so that the seating bench height was too high for the students.

**Table 6: Knee height – T-test chart**

	Test value = 41.38 cm			
	T	df	Sig. (2-tailed)	Average difference
Knee height	-15.42	1,388	0.000	-2.4

### 3.1.3 Eye height relative to elevation of classroom's blackboard/whiteboard from floor (existing)

As a result of the calculations, the average height of the classroom's blackboard/whiteboard from the floors of all of the examined classes was calculated to be 67.23 cm, while the average eye height (sitting) of all of the students was calculated to be 63.79 cm (standard deviation  $\pm 5.41$ ). When we compared the calculated value with the students' eye height (sitting), the Sig. value was calculated to be less than 0.05. In the T-test chart, Table 7, the p value was calculated to be 0.000, which is less than 0.05. There was a difference between the averages: when we compared them, we concluded that the students' eye height (sitting position) in the school that was examined – i.e., 63.79 cm – was lower than the height of the classroom's blackboard/whiteboard from the floor.

**Table 7: Eye height (sitting) – T-test chart**

	Test value = 67.23 cm			
	t	df	Sig. (2-tailed)	Average difference
Eye height (sitting)	-15.84	1,388	0.000	-3.44

There was a greater gap between the seat surface and the desk surface than required. The results highlighted that the desktop height was too great for both genders, as was the seat height; in addition, the seat width was too narrow for all of the students and the seat depth was too great for most of the students. Therefore, most of the existing school furniture was found to be unsuitable for the students. The recommended dimensions for classroom furniture are shown in Table 8 (later in this article).

Seat height is related to popliteal height; and so, for the purpose of adjustable designs, it should be 5<sup>th</sup> percentile of the popliteal height of girls to the 95<sup>th</sup> percentile of the popliteal height of boys within allowable allowance for shoe clearance. The working height for writing should be at elbow level or above. Therefore, the 5<sup>th</sup> percentile (for girls) to the 95<sup>th</sup> percentile (for boys) of elbow rest height should be considered for the desktop height from the seat. The seat width needs to be the hip breadth of the 95<sup>th</sup> percentile of girls for maximum sitting space, and the seat depth should be designed on the basis of the buttock popliteal length of the 5<sup>th</sup> percentile girls for a better sitting posture.

The mismatch percentages were then calculated for the proposed dimensions.

As can be seen from the above calculations, furniture in the examined school should be redesigned so that it is suitable for primary and secondary students, and is based on their anthropometric measurements.

In the study, the proposed dimensions were compared with the existing dimensions. The proposed dimensions reduced the mismatch percentages for both boys and girls: from 82.4 per cent to 2.58 per cent (seat height), from 98 per cent to 6.3 per cent (seat width), from 86 per cent to 10.37 per cent (seat depth), and from 98 per cent to 11.38 per cent (desktop height) for boys; and, similarly, from 92.86 per cent to 5.32 per cent (seat height), from 91.28 per cent to 7.39 per cent (seat width), from 84.33 per cent to 12.83 per cent (seat depth), and from 97.85 per cent to 16.27 per cent (desktop height) for girls. Based on these reduced percentage mismatches, the proposed dimensions (in cm) of the newly designed furniture are shown in Table 8.

### 3.1.4 Related calculations

In the study, a regression analysis (a dimension differences regression analysis between classes) and an Anova test were performed. The variance between the independent variable 'weight' with 'class' was calculated. In addition, the T-test and the significance analysis (the Mann-Whitney U test statistic) were calculated. The significance analysis results were changed by considering students' grades.

### 3.1.5 Post-Covid-19 policies related to schools

The Covid-19 pandemic has caused abrupt and profound changes around the world, and has been the worst shock to education systems in decades, with long school closures combined with a looming recession. It will set back any progress made on achieving global development goals, particularly those focused on education, in the wake of schools being shut all around the world. While countries have been at different points in their Covid-19 infection rates, currently around 1.6 billion children in 186 countries have been affected by school closures because of the pandemic. UNESCO has reported that the Covid-19 pandemic had resulted in unprecedented global disruption to education [20]. As a result, education has changed dramatically with the notable rise of e-learning through which teaching is undertaken remotely via digital platforms.

The Covid-19 pandemic and the associated rapid spread of the virus compelled many governments to declare a national state of disaster. Some countries implemented a series of regulations and protocols to mitigate the spread of the virus. These regulations governed learner access across educational sectors, and cut across educational sub-sectors, from pre- to post-schooling.

Standard classrooms in Turkey are usually designed to support class sizes of about 50 students. To accommodate the return of students in a post-Covid-19 world, classrooms will need to decrease in density and plan for greater flexibility and adaptability to address longer-term needs.

UNESCO has reported that, in a post-Covid-19 world, there will be a great need to repair the separations that have arisen as a result of quarantines and distancing restrictions [20]. Therefore, post-Covid-19 strategies, policies, and protocols in schools will need to include protecting the social dimensions of space in the school and classroom environments; adding physical barriers between students; arranging spacing between students following physical distancing (social distancing) guidelines – i.e., about two metres (six feet) between students as a physical 'shield'; enabling students to stay in one place as teachers move from classroom to classroom, and students do not face one another; frequently cleaning schools, and ensuring that students and teachers wash their hands; adding high transparent screens on up to three sides of each table for shielding purposes; ensuring a minimum distance of two meters between desks (in all directions); adding mobile screens between each individual table and desk or chair to provide shielding; and rearranging individual desks to avoid face-to-face interaction between students. When the educational system is resumed, preschool, primary, and secondary school students will face the greatest challenges regarding social distancing, self-cleaning, and wearing masks. By defining the work/study areas in schools, students will understand their own limits and boundaries and the disease's transmission systems. In post-Covid-19 schools, furniture will need to include protective screens that guarantee a separation between students. Therefore, the following improvements in schools should be made to keep every child safe in the post Covid-19 period, as stated in post-Covid-19 policies and protocols:

- Schools' heating, ventilating, and air conditioning (HVAC) systems should be replaced with those with a higher filtering rate, such as MERV 13 or MERV 17 filters.
- Portable high-efficiency particulate air (HEPA) and ultraviolet germicidal irradiation (UVGI) filtration systems should be used, especially in higher-risk areas.
- School management should take precautions on indoor air to reduce the spread of Covid-19 in the post-Covid-19 period.
- Humidification systems are rarely installed in schools' learning-environments. Since humidity levels of between 40 and 60 per cent have been shown to reduce the viral spread of Covid-19, humidification systems similar to health systems should be used in schools.
- About 60 cm high transparent table top-mounted screens on three sides of each classroom's tables/desks should be added to provide shielding in the post-pandemic period while maintaining sight lines to classmates, teachers, and content.
- A moveable screen provides a transparent shield between teachers and students, and can be moved, if desired, to provide shielding while using the whiteboard.
- Moveable tables maximise flexibility in supporting multiple learning modes, and can be adapted to the school's needs over time.



- School furniture must fit the students' anthropometric dimensions to increase their performance in class.
- School management must conduct a comprehensive Covid-19 transmission hazard assessment in classrooms to identify/define potential hazards.
- Landmarks, signs, and coloured tape marks on schools' floors should be placed two metres (six feet) apart to indicate physical distancing (social distancing).

By applying the above items, we could provide safer and healthier classrooms to our students. Authorities should also construct new schools that satisfy post-Covid-19 requirements. In furniture design, flexible furniture would be more popular, since it would meet Covid-19 requirements; fixed or heavy school furniture, for example, cannot support the physical distancing (social distancing) requirements. A mixture of seating types – benches, shared collaborative tables, and lounge seating – provide students with maximum choice and control. Furniture designers should be required to employ post-Covid-19 design strategies by satisfying the criteria set out above to provide a healthy environment in schools in a post-pandemic world.

### 3.1.6 New classroom furniture design in the light of post-Covid-19 policies

While designing classroom furniture for students, it is important to consider the anthropometric dimensions and data of primary and secondary school students' safety, health, and well-being in order to satisfy post-Covid-19 policies and protocols [35, 36, 37, 38, 39]. We should also consider the effects of students sitting for long periods on their musculoskeletal systems in the light of post-Covid-19 policies. These also require mobile screens to be added between each individual table or desk and chair to provide shielding between students.

Students generally use chairs or benches and desks or tables that do not fit their anthropometric dimensions. Although students in the same classroom are the same age, their anthropometric dimensions vary from one to the next. Poorly-designed classroom furniture causes ergonomic diseases, especially back pain. The width and height for the new post-Covid-19, ergonomically-centered classroom furniture (desks and chairs) are presented in Table 8.

**Table 8: Proposed classroom furniture dimensions for Turkish school students**

Furniture dimensions (cm)	1st grade	2nd grade	3rd grade	4th grade	5th grade	6th grade	7th grade	8th grade
Width of chairs (CW)	30	31	33	34	36	40	41	43
Width of desks (DW)	39	40	41	42	46	47	48	49
Height of chairs (CH)	34	35	39	40	42	43	44	46
Height of desks (DH)	65	67	70	74	76	78	80	82
Distance between desks and chairs (DC)	5-6	6-7	7-8	8-9	9-10	10-11	10-11	11-12
Distance between chairs satisfying post-Covid-19 policies	1.80	1.80	1.90	1.90	1.90	1.90	2.00	2.00

## 4 CONCLUSION

The Covid-19 pandemic has had a negative impact on educational systems globally, with school closures significantly disrupting education. UNESCO has reported that the pandemic has led to unprecedented disruptions to formal education, with up to 1.6 billion students, or 94 per cent of the world's students, forced to be out of school in April 2020 [20]. Therefore, many EU countries implemented measures to support remote teaching and learning, starting with video lessons via television and using online distance-learning platforms. Some schools organised online professional development and peer-to-peer learning opportunities for teachers to meet remotely and to share their experiences with online learning during the Covid-19 pandemic crisis.

School furniture is an environmental factor that is often neglected, even though it plays an important role in the effectiveness of a student's learning. Children spend as much as nine hours at their desks every day, and almost 83 per cent of them sit at desks and chairs that are not suitable for their body height. So

classroom ergonomics plays an important role in the learning environment. Educational institutions upgrade their curricula, and yet they do not pay much attention to classroom ergonomics, such as the seating arrangements. Desks and chairs in the classroom are one of the most crucial elements of a learning environment. Classroom furniture must fit the children, allow movement, and so encourage a good posture. Movement plays an important part in seating. All of these factors have a major impact on students' learning, and can greatly improve their performance if done correctly.

The aim of the study was to evaluate the relationship between classroom furniture and students' anthropometric measurements from a sample population of 1 388 students from one school in Turkey. A significant mismatch was identified between the classroom furniture's dimensions and students' body dimensions. The seat height and desktop height were found to be too high, and the seat width was too small for both boys and girls. As a result, they were affected by various musculoskeletal disorders, and lost their attention on their studies. The research has suggested that classroom furniture should be designed on the basis of anthropometric measurements of the students so that they can avoid experiencing discomfort and pain. Based on students' anthropometric measurements, the furniture proposed in Table 8 would be much more suitable for the students.

In the study, the descriptive statistics and anthropometric measurements of children according to age and gender were calculated. In addition, it was found that there was a significant difference or mismatch between the measurements and anthropometric dimensions of students in relation to gender, age, physical activity, social status, and nationality. Given the results of the study, school management should consider the gender and age of their students in the light of post-Covid-19 policies and protocols when procuring classroom furniture.

An independent t-test (with a 95 per cent confidence interval) was performed to examine the differences in measurements between the various tools used to gather the anthropometric data. The results showed that no statistically significant difference ( $p > 0.05$ ) was identified between the measurement methodologies or tools for all of the anthropometric variables that were gathered. Given the results thus obtained, it is worth mentioning that the current anthropometric variables were normally distributed. The t-tests and one-way ANOVAs were used to compare the means. Considering the data of seated popliteal and elbow height gathered from the students, for both chairs and desks, it was possible to compare the data and to define different sets of furniture to cater for the whole observed population.

In the study, the anthropometric data showed that there was a difference or mismatch between the students' anthropometric measurements and the available classroom furniture that would cause musculoskeletal pains/disorders (MPD) and several physical anomalies. The major mismatch identified by the study was that primary and secondary school students' dimensions and anthropometric measurements did not match the existing desk-seating bench combinations. The furniture's dimensions were not suitable for primary and secondary school students: generally the seating bench height was lower than the measured dimensions of the students, the seating benches were too narrow, and the height of the desk and seating bench was too low, although sometimes it was too high. In order to minimise the level of mismatch between Turkish students and their classroom furniture, it should be designed correctly, taking into consideration their anthropometric measurements. In addition, students' anthropometric measurements are affected by their gender, age, physical activity, social status, and nationality. These parameters need also to be considered in the design of students' furniture.

Students' existing seating benches need to be changed to chairs that meet post-Covid-19 policies and protocols. If a new seating bench/chair need to be bought by the school management, then the chair dimensions proposed in Table 8 should be used. However, in order not to increase the school's budget in the post-Covid-19 period, school managements should retain the existing seating benches that match the dimensions presented in Table 8. The major objective of this study was to design ergonomic classroom furniture for students that accommodated at least 95 per cent of the student population from first grade to eighth grade. The proposed new design dimensions of ergonomic classroom furniture that fulfils post-Covid-19 policies and protocols would reduce students' musculoskeletal pains and disorders. When students return to classrooms, one of the first things they will have to learn is how to navigate the post-Covid-19 environment of physical distancing and limited interaction. It will take some getting used to, but classroom furniture will play a significant role in helping students and teachers to adhere to the protocols. UNESCO has reported that, in a post-Covid-19 world, there will be a great need to heal the separations that have arisen as a result of quarantines and distancing restrictions [20]. Therefore, post-Covid-19 strategies, policies, and protocols in schools include protecting the social dimensions of space in the school environment and classrooms; adding physical barriers between students; arranging spacing between

students to meet social distancing guidelines – i.e., about two metres (six feet) between students – as a physical ‘shield’; enabling students to stay in one place as teachers move from classroom to classroom; keeping students from facing each other; cleaning schools frequently and requiring students and teachers to wash their hands often; adding high transparent screens to three sides of each table for shielding purposes; ensuring a minimum distance of two metres between desks in all directions; adding mobile screens between each table or desk and chair to provide shielding; and rearranging desks to avoid the face-to-face interaction of students. The necessary improvements in schools should be made to keep every child safe and also satisfy post-Covid-19 strategies, policies, and protocols:

- Students’ classroom seating positions and furniture should support a healthy posture.
- HEPA and UVGI filtration systems should be used, especially in higher-risk areas.
- 60-cm high transparent table-top-mounted screens should be fitted on three sides of each table, to provide shielding.
- A moveable screen should provide a transparent shield between the teacher and the students.
- Landmarks, signs, and coloured tape marks on school floors should be placed two metres (six feet) apart to indicate social distancing.

In a post-pandemic world, the density and arrangement of students in school should be arranged in line with post-Covid-19 policies and protocols – e.g., maintaining the physical distancing or shielding needed for safety and psychological comfort when students return to school. By applying the recommended dimensions for ergonomically-oriented classroom furniture, the comfort level of students in satisfying post-Covid-19 policies and protocols would increase, and the new post-Covid-19 designs would reduce musculoskeletal disorders and their related pains and aches.

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