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Design and Development of an Ergonomic Chair for Students in Educational Settings

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Abstract

Background: Proper designing of chairs based on ergonomics increases efficiency, promotes quality of education, leads to correct posture in students, and reduces risk of musculoskeletal disorders.
Objectives: The aim of this study was to design and develop an ergonomic chair, based on anthropometric data of students in educational settings.
Methods: Anthropometric parameters were obtained from a stratified-random sample of 207 students. The data were analyzed using the SPSS 20 software, and the results were extracted as mean, standard deviation, and percentiles. The chair was planned in the CATIA software and developed by a three-dimensional print.
Results: In this study, an ergonomic chair was designed based on anthropometric data from students. The seat height, depth, and width of the chair were determined as 44 cm, 42 cm, and 42.15 cm, respectively. The height of the desk was adjustable in 19 to 29 cm, and the depth and length of the desk were considered as 51 cm and 65 cm. The width and height of the backrest were also 54 cm and 44 cm, and the backrest angle was adjustable in 95° to 105°.
Conclusions: An ergonomic chair with adjustable parts was designed to achieve a well-match between anthropometric characteristics of students and the furniture. Such chair can reduce musculoskeletal disorders in students. Some ergonomic characteristics of this chair include adjustability of footrest, backrest, armrests, and desk. A chair with such characteristic can be used by many students with different body sizes.

Keywords: Design, Ergonomic, Chair, Educational Setting

1. Background

Education is the most effective means to ensure economic growth and national development in countries (1). University is one of the educational settings in training of students. Effective training can be achieved in a safe and stress-free space in classrooms (2). Physical environment of educational facilities can help teaching, learning, and academic performance (3, 4), while inadequate facilities can cause stress and agitated behaviors in students (5).

Physical environments of classrooms have a vital role in student's satisfaction (6), and a higher level of satisfaction can increase the level of skills, mentality, and knowledge of students (7). University is the workplace of many students around the world, and chairs have become an important physical element of the classroom and learning environment (2, 8). Educational furniture is used in classrooms of many colleges, institutes, and universities (9, 10), and students spend a major part of their time sitting on this furniture in classrooms (9, 11-13). Therefore, they are exposed to risks associated with prolonged sitting in a static and awkward posture (13). These risk factors are generally created with inappropriate chairs (14).

Improper design of chairs is one of the reasons of inappropriate sitting positions (15), which can lead to bad posture, fatigue, severe psychological stress, and effects on students' performance (9, 14, 16). The relationship between awkward body posture and cognitive issues, such as consciousness, discomfort, and reaction time has also been investigated by some studies (17). Many complications can arise from using inappropriate chairs, such as lower back pain, pain in the spine, neck, shoulders, arms, and paralysis of muscles (15, 18).

Also, static posture reduces flexibility and softness of intervertebral discs (19) and causes severe muscle tension due to reduced disk feeding and limitation of blood flow

(20, 21).

Studies have shown that inappropriate design of chairs and their disproportion with body dimensions in the long-term not only influences physical growth, poor postures, and musculoskeletal disorders, yet also decreases student's learning interest, even during the most stimulating and interesting lessons (8, 22), and indirectly effects educational efficiency and focus (13, 23). Recent studies have also revealed that disproportion between users' anthropometric dimensions and available furniture is one of the factors that reduces concentration and increases fidgeting in individuals (24).

According to statistics, over 4 400 000 students are studying in Iran; therefore, lack of standard desks and chairs can influence health of this stratum (25). Using appropriately designed furniture may reduce fatigue and discomfort in sitting posture and allows students to sit comfortably for longer periods of time, consequently increases concentration and learning (13). Efficient furniture is expected to help learning by providing a stress-free and comfortable workstation (8).

Equipment should be designed based on anthropometry and ergonomics principles to reduce accidents and symptoms in order to increase efficiency (26). Anthropometry is defined as measuring dimensions of the body, including body size, shape, strength, capacity, and volume for designing aims (9, 27, 28). Dimensions of the body in users have an important role in designing workstations that fit the normal posture (29). True size of desk and chair has been determined by measurement of body dimensions in users (22). Studies have shown that anthropometric parameters are important factors in designing desks and chairs for students (8, 26). This furniture has a low comfort for students as anthropometric data were not used in its design (9, 10). Using anthropometric measurements in design improves students' comfort (8, 30) and reduces musculoskeletal disorders (MSDs) (18, 31), and consequently improves their performance (10, 32). Furthermore, MSDs are defined as injuries in the muscular and nervous systems, including muscles, bones, joints, tendons and ligaments, nerves, and blood vessels, which can limit usual activities of students (33-35). Work-related MSDs are one of the consequences of awkward posture that can influence efficiency, performance, well-being, and quality of work (36).

Designing comfortable furniture (28) leads to health, safety, productivity, well-being, and motivation to study (16, 31, 37). Thus, proper designing of chairs based on ergonomics and anthropometric characteristic increases efficiency and promotes quality of education, leads to correct posture in students, and reduces musculoskeletal disorders (2).

A large number of studies, worldwide, have shown a mismatch between students' anthropometric characteristics and dimensions of classroom furniture. For example, Panagiotopoulou et al. reported that classroom chairs are too high and too deep; desks are also too high for pupils (20). Gouvali and Boudolos found that desk and seat height were larger than accepted limits for most children (26). In Iran, studies have also shown mismatch between students' body dimensions and classroom chairs and desks. In a study conducted by Zarei et al., seat dimension and students' dimensions matched only in desk length parameters (2). Bayatkashkoli and Nazerian reported that dimensions of chairs were greater than acceptable limits for most students (38). Other studies revealed a mismatch between characteristics of existing chairs and anthropometric dimensions of students (13, 39). Although there are a large number of studies, worldwide, in which classroom furniture has been designed and developed for students, few studies have been conducted on designing furniture for universities in Iran. Khanam et al. designed seating furniture for classroom settings based on anthropometric data of undergraduate students (40), and Mokdad and Al-Ansari designed ergonomic school furniture for Bahraini students (32). In some studies, researchers designed ergonomic chairs and furniture for university students in Sri Lankan and India (8, 9, 16). Oyewole et al. designed ergonomic and adjustable classroom furniture for first graders at an elementary school (22).

In these studies, designing of school furniture has been traditionally based on anthropometry and biomechanics of the human body. Few studies have been conducted on designing ergonomic furniture for educational settings in this field, in Iran. Many aspects of design, including comments and suggestions from users of this furniture have not been considered. It should also be noted that no specific software has been used for designing in these studies and only the dimensions and features of the chair are presented.

Anthropometry has three basic principles that are being considered in designing various furniture, depending on their type. These principles include: "Design for extreme", which can be designed based on the 95th percentile male or design based on the 5th percentile female; "design for an adjustable range", which can be considered both 5th female and 95th male and this principle has been suggested by many researchers in designing; "design for the average", which is used whenever the use of adjustability is impractical (9). This study used principles of "design for extreme" and "design for an adjustable range" for designing different parts of a chair.

2. Objectives

This study aimed at designing and developing an ergonomic and anthropometric chair for students in educational settings based on standard dimensions.

3. Methods

3.1. Participants and Sample Size

In this study, anthropometric parameters were obtained from students of Qazvin University of Medical Sciences. The total number of students was 2563. Based on previous studies (2) and Equation 1, sample size was calculated as 132. However, collected data exceeded the calculated sample size, and 207 students participated in the study. In this study, male and female students at the age of 18 to 27 years, studying at undergraduate and postgraduate levels, were selected through stratified-random sampling.

$$n = \frac{Nz^2\delta^2}{Nd^2 + z^2\delta^2} \quad (1)$$

This study was approved by the Ethical Committee with a proprietary ID of IR.QUMS.REC.1395.187. Informed consent form was obtained from all participants.

3.2. Anthropometric Measurements

Static anthropometry was used to measure dimensions of the body. Data of static anthropometry are related to dimensions and sizes of the body in a fixed structural position that are measured by specific anatomical points in a specific condition.

An anthropometer with adjustable chair and footrest, digital calipers with precision of 0.1 and 0.5 mm, plastic ruler, flexible measuring tape, and a goniometer were used to measure the body dimensions of students. Then, the results were recorded in an anthropometric checklist. Subjects wore a light dress with no shoes. All measurements were taken when the subjects were sitting in a full straight posture, so that the knees and ankles formed right angles and with feet on the floor. The recorded anthropometric measurements were stature, sitting height, shoulder height (sitting), elbow height (sitting), shoulder breadth, popliteal height, knee height, hip width, elbow to elbow width, elbow-fingertip length, buttock-popliteal length, buttock-knee length, abdominal depth, forearm width, thigh thickness, and weight. Definitions of the above-mentioned anthropometric dimensions are presented in Table 1.

Figure 1 shows 15 dimensions of the body used for designing of the chair.

3.3. Data Analysis

The data were analyzed using the SPSS 20 software, and the results were extracted as mean, standard deviation, and percentiles. Thereafter, standard dimensions for designing an ergonomic chair were estimated. Then, the chair was planned in the CATIA software, and the prototype of the chair was developed by three-dimensional print. The material used for developing this model was PLA bioplastic.

Also, in this planning, the needs of the chair design were identified using students' and expert professors' suggestions and opinions to improve the design and increase the perfection and popularity of the designed chair.

4. Results

According to the results, 82 (39.6%) of cases were male, and 125 (60.4%) were female; 46.4% were studying health, 33.8% paramedical, 15.5% nursing and midwifery, and 4.3% medicine and dentistry. Mean and standard deviation of age was 20.82 $\pm$ 1.55 years. Descriptive statistics of anthropometric parameters for males and females and all students are presented in Tables 2 and 3.

Table 4 shows various criteria, which have been suggested to determine the dimensions for designing chairs for students. Two principles of anthropometry were used to determine these criteria, which include "design for extreme" and "design for an adjustable range". For example, principle of "design for an adjustable range" was used for designing the height of the desk. It should be noted that in this study, different dimensions of the designed chair were compared with standards ISIRI 9697-1, ISIRI 7494, and BS5874.

The data collected in this study can be used for designing adjustable and non-adjustable chairs for students. In many researches it has been recommended to design adjustable furniture whenever possible. However, factors, such as cost, difficulty to prepare, mechanism of adjustability and time make limitations in designing and development of adjustable furniture (9). In this study, some parts of the chair were designed to be adjustable in order to allow comfort and flexibility.

Figure 2 shows the designed chair from different sides.

5. Discussion

Long-term inappropriate posture and discomfort, associated with improper design of chairs and desks used at schools and universities, are factors that may affect learning and academic performance and physical growth of students. Therefore, chairs should be designed based

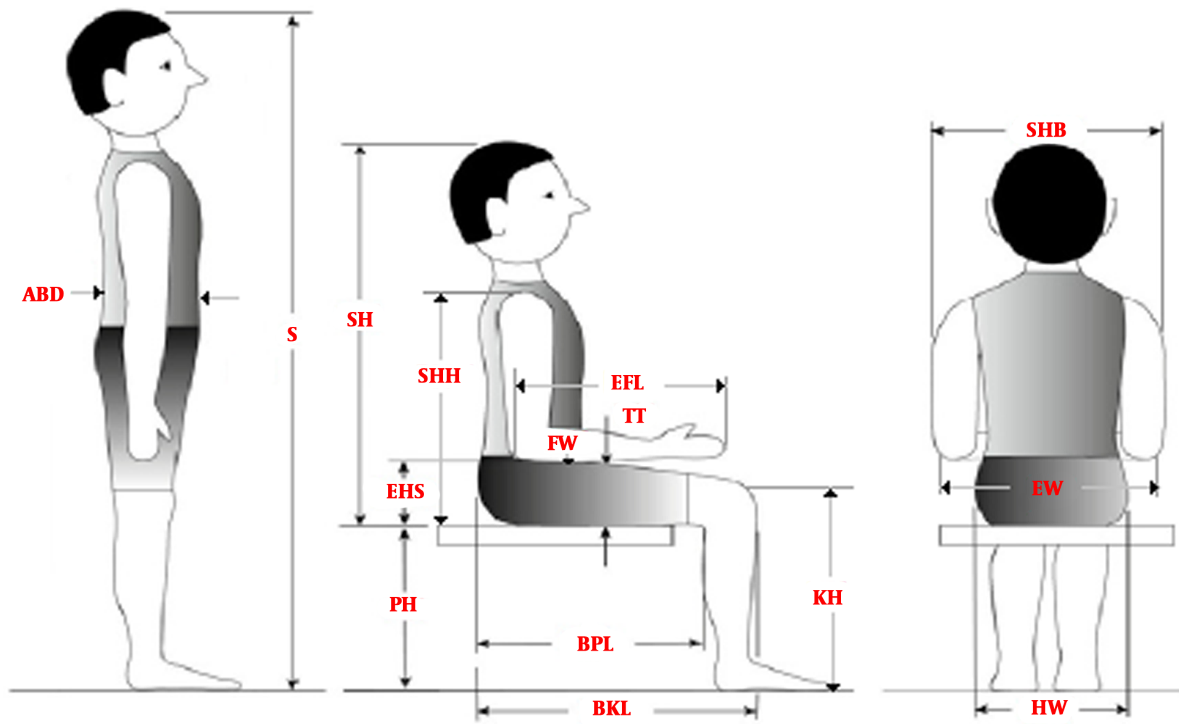

Figure 1. Anthropometric dimensions required in chair design. Abbreviations: S, stature; SH, sitting height; SHH, shoulder height; EHS, elbow height sitting; SHB, shoulder breadth; PH, popliteal height; KH, knee height; HW, hip width; EW, elbow to elbow width; EFL, elbow-fingertip length; BPL, buttock-popliteal length; BKL, buttock-knee length; ABD, abdominal depth; FW, forearm width; TT, thigh thickness.

Figure 2. Designed chair from different sides

Table 1. Description of Dimensions of the Body for Design of the Classroom Chair

Body Dimensions	Description of Body Dimensions of Students
Stature	Vertical distance from the floor to the top of the head, and measured with the subject erect and looking straight.
Sitting height	Vertical distance between the top of head and the surface of the seat surface that measured with the subject erect and looking straight ahead.
Shoulder height sitting	Vertical distance from the top of the shoulder at the acromion to seat surface.
Elbow height sitting	Vertical distance from the bottom of the tip of the elbow to the seat surface and taken with a 90° angle elbow flexion.
Shoulder breadth	Maximum horizontal breadth across the shoulders.
Popliteal height	Vertical distance from the floor to the posterior surface of the knee with 90° knee flexion.
Knee height	Vertical distance from the floor to the top of the knee cap.
Hip width	Horizontal distance measured in the widest points of the hips in the sitting position.
Elbow to elbow length	Horizontal distance across the lateral surfaces of the elbows.
Elbow-fingertip length	Horizontal distance from the outer surface of the elbow to the tip of the tallest finger.
Buttock-popliteal length	Horizontal distance from the posterior surface of the buttock to the popliteal surface.
Buttock-knee length	Horizontal distance from the back of the buttock to the front of the knee cap.
Abdominal depth	Horizontal distance from vertical reference plate to front of the abdomen in standard sitting position.
Forearm width	Maximum width of the forearm when it is straight.
Thigh thickness	Vertical distance from the highest point of thigh to the seat surface.

on anthropometric dimensions of users. Matching between dimensions of chairs and users' anthropometric dimensions and ergonomics indices leads to more comfort for consumers. Standard design of chairs can promote anatomical postures and comfort, which prevent inappropriate body postures. This factor can also reduce the risk of musculoskeletal disorders and increases efficiency and concentration of students at classrooms (13, 23, 26). In this study, an ergonomic chair was designed based on ergonomics principles and anthropometric data obtained from students to allow comfort and productivity.

Anthropometric dimensions that form the basis for the dimension of seat height was the popliteal height and the seat height of standard chair in this study was determined based on the 5th percentile of females' popliteal height. The seat height of the chair should be matched with 5th percentile of users' popliteal height so that short persons are also able to put their feet on the floor easily and do not feel pressure in different parts of their body when sitting on the chair. In this study, standard seat height without considering shoes was 33 cm, which is consistent with findings of similar studies (2, 41). Furthermore, with 3 cm for heel height and 8 cm for the height of footrest, the seat height was considered 44 cm, which is in accordance with BS5873 and standard ISIRI 7494. In the study of Thariq et al., this dimension was considered 44.5 cm, which is similar to the present study (8). The footrest of the designed chair was adjustable for short persons, who cannot fully fit their legs on the floor, if they want to place their legs on this footrest. Also, tall persons can fully close it if they do not want to use the footrest. A basket is also available under the chair for additional equipment.

The seat depth was calculated 42 cm based on 5th percentile of buttock-popliteal length, which matches the standard BS5873 and ISIRI 7494. This figure was reported as 40.9 cm (2) and 40 cm (40) in other studies, which are less than that obtained in the current study. In contrast, some studies reported this dimension as 43.4 cm (8), 44.81 cm (16), and 45 cm (9), respectively, which is more than the current study. Mismatch between seat depth and buttock-popliteal length of users can lead to bending of the trunk and head and extending the arm forward and, consequently, leading to pain in the back, shoulders, and arms in the long term and also creating problems in using the backrest. The high depth of seat leads to pressure on the thighs and disruption of the circulatory system; the low depth of the seat leads to pressure on back and knees to avoid falling (42). The front edge of the seat has a curvature that protects the underlying thighs, and the casualty in front of the seat prevents from pressure to different parts of the feet. This feature is in accordance with the ISIRI 9697 - 1 standard.

The hip width was considered for determining the dimension of the seat width. The standard seat width was determined based on the 95th percentile of hip width that was reported as 42.15 cm. This figure in the study of Zarei et al. (2) and Kashif et al. (16) was reported as 41 cm and 30.03 cm, respectively, which is less than those calculated

Table 2. Anthropometric Indices of Male and Female Students

Anthropometric Parameters[a]	Male				Female			
	5th	50th	95th	Mean ± SD	5th	50th	95th	Mean ± SD
Stature	164	177	186	176.5 ± 6.66	154	162	170	162.6 ± 5.32
Sitting height	86	92	98.8	92.2 ± 38.2	81	85	91	85.5 ± 3.08
Shoulder height (sitting)	57.15	64	68.5	63.3 ± 3.15	54.65	58	62.85	58.4 ± 2.52
Elbow height (sitting)	18.65	25	29	24.9 ± 3.15	19.3	24	29	24.2 ± 2.57
Popliteal height	36	41	44.5	40.9 ± 3.43	33	38	41	37.5 ± 2.54
Knee height	47	51.75	62.85	51.7 ± 2.85	44	48	53	48.4 ± 2.42
Shoulder breadth	34.09	37.42	42.39	37.8 ± 2.27	32.18	35.62	38.55	35.6 ± 2.01
Hip width	32.37	36.5	40.6	36.5 ± 2.27	32.92	36.9	42.15	36.9 ± 2.69
Elbow-fingertip length	44.13	47.2	51.18	47.4 ± 2.07	38.8	42.2	45.6	42.4 ± 2.17
Buttock-popliteal length	46.15	50	58	50.4 ± 3.28	42	47	52	46.8 ± 2.95
Buttock-knee length	57.15	61	69.7	62.2 ± 3.42	54	59	64	58.6 ± 3.19
Abdominal depth	21	24	28	24.3 ± 2.15	19.3	22	28	22.9 ± 2.81
Forearm width	6.8	8.05	9.49	8.1 ± 0.8	6.09	7.1	8.5	7.19 ± 0.73
Thigh thickness	13	16	20.42	16.1 ± 2.34	11	14	18	13.9 ± 2
Elbow to elbow width	35.76	43.46	53.93	43.7 ± 5.37	34.64	39.91	46.85	40.22 ± 3.83
Weight	55	70	87.82	70.3 ± 9.6	44	57	74.1	57.8 ± 9.73

[a] All dimensions are in cm.

Table 3. Anthropometric Indices of Students

Anthropometric Parameters[a]	All Students					
	5th	50th	95th	Min	Max	Mean ± SD
Stature	155.2	166.5	184	149	203	168.1 ± 9.01
Sitting height	81	88	96.8	78	103	88.1 ± 4.73
Shoulder height (sitting)	55	60	67	52.5	70	60.4 ± 3.75
Elbow height (sitting)	19.2	24.5	29	17	36	24.5 ± 2.83
Popliteal height	33.7	39	43.5	29	63	38.9 ± 3.36
Knee height	45	50	55	43	59	49.7 ± 3.08
Shoulder breadth	32.41	36.44	40.74	31.3	44.42	36.46 ± 2.36
Hip width	32.68	36.73	41.33	31.2	45.24	36.76 ± 2.54
Elbow-fingertip length	39.3	44.15	49.76	34.2	52.36	44.37 ± 2.23
Buttock-popliteal length	43	48	55	38	61	48.31 ± 3.57
Buttock-knee length	54.5	60	66.3	49.1	72	60.1 ± 3.71
Abdominal depth	20	23	28	16	34	23.47 ± 2.66
Forearm width	6.28	7.47	9.27	4.46	9.96	7.6±0.88
Thigh thickness	11.5	14.93	19.18	9	23	14.78 ± 2.4
Elbow to elbow width	35.17	40.92	51.08	25.53	56.15	41.58 ± 4.8
Weight	44.4	62	80.9	41	99	62.8 ± 11.45

[a] All dimensions are in cm.

Table 4. Recommended Dimensions for Design of the Chair

Chair Features	Anthropometric Data	Design Dimension (Cm)	Criteria Determinant
Seat height	Popliteal height	44	5th percentile (female) of popliteal height
Seat depth	Buttock-popliteal length	42	5th percentile (female) of buttock-popliteal length
Seat width	Hip width	42.15	95th percentile (female) of hip width
Desk height	Elbow height (sitting)	19 - 29	5th - 95th percentile (all) of elbow height
Desk length	Elbow-fingertip length	51	95th percentile (male) of elbow-fingertip length
Desk width	Elbow to elbow width	65	95th percentile (male) of elbow to elbow width
Armrest width	Forearm width	9.49	95th percentile (male) of forearm width
Backrest height	Shoulder height (sitting)	54	5th percentile (female) of shoulder height
Backrest width	Shoulder breadth	44	95th percentile (male) of shoulder breadth
Backrest angle	-	95° - 105°	Bs5873

in this study. This dimension was estimated as 43 cm (9) and 43.6 cm in other similar studies (8). The seat width in the designed chair in this study was considered as 45.5 cm due to increase in the thighs clearance, which is in accordance with BS5873 and standard ISIRI 7494. This chair also has an armrest on both sides; therefore, the seat width was considered larger so that it did not create any problem and limitation in sitting and standing up. Therefore, this factor causes people to feel no pressure on their hip and the sides of thighs when sitting on it.

The desk of the designed chair was adjustable, and adjustable height of this desk was determined by 5th to 95th percentile of sitting elbow height of all students, which was 19 to 29 cm. The height of the armrests and the desk of the chair were adjustable because different people can adjust the height of their elbows and place it along their elbows so that they do not keep their shoulders up or down and feel no pressure on the shoulders and various parts of their hands. According to Grimes, mismatch between the sitting elbow height and desk height can lead to pain in the shoulders and neck (43). The adjustability of the desk in the study of Kashif et al. was reported as 22.64 to 24.26 cm (16), and in the study of Taifa and Desai, it was reported as 15.6 to 24.5 cm (9), which are in contradiction with the present study. One of the reasons for the conflict was that these studies were conducted in different countries; consequently, the body dimensions of students were different from country to country. In some studies, such as Thariq et al.'s research, this dimension was not considered adjustable, and a fixed height of desk was estimated as 22.9 cm (8). It should be noted that the softness of hand placement on the elbow support in the designed chair is based on the recommendation of Pheasant.

The 95th percentile of elbow-fingertip length of male students was used to determine length of the desk and this dimension was 51 cm. This size in Zarei et al.'s study was 50 cm, which had one centimeter difference with the current study (2). In similar researches, this dimension was different from the current study (8, 9). One of the reasons for this contradiction was the difference in dimension and percentile used in the mentioned studies, so that they used from buttock-knee length (9) and 50th percentile of elbow-fingertip length (8) for this purpose. The desk of the chair designed in the present study had the ability to move forward and backward, which makes it easy for people to adjust the desk at the desired distance from their body. This also causes people with high abdominal depth to sit comfortably without pressure. This desk can be folded and stepped out of the chair and the students can close the desk if they do not want to use it.

Desk width was obtained as 53.93 cm based on 95th percentile of elbow to elbow width and due to the design requirements and ensuring that the desk was placed on the chair's armrests; this dimension was considered 65 cm. The surface of the desk was considered wide enough to be suitable for both right-handed and left-handed students and the person should not bend the waist and neck when writing. Also, there was enough space to put additional stationery, and it had a groove where students could put their pen and pencil.

Armrest width was determined based on 95th percentile of forearm width to the elbows and forearms of the majority of students was appropriately positioned on it. On this chair two armrests were considered to support both arms.

Shoulder height was used in determining the height of backrest and the percentile used for this purpose was 5th percentile and this design facilitated the movement of the waist and arms (32). Also, the upper part of the backrest had two grooves to place the students' bag. The backrest height in the study of Taifa and Desai was reported as 50 cm, which was different from the current study (9) because of differences in studied countries and people. The upper and lower edges of the backrest were considered in a curved form, based on the ISIRI 9697 - 1 standard.

The backrest width of the chair was calculated as 44 cm based on 95th percentile of student's shoulder breadth and standard ISIRI 7494, and the curvature of this backrest supported the lumbar well. In some studies, this dimension was reported as 43.6 cm (8) and 42 cm (9), which was similar to the current study. Mismatch between the backrest width and shoulder breadth can lead to fatigue of the scapula and pain in the shoulders (2).

The backrest angle should be adjustable to provide full lumbar support and posture of students can be proper and varied (16). Therefore, one of the features of this chair was its ability of adjustment to the backrest angle, which has a pin for the person to adjust the backrest at the desired angle for comfort. The adjustable angle of backrest was considered from 95° to 105°, based on British Standard (BS5873) and standard ANSI-HFES 100/1988. Backrest angle in other similar studies was 96° (8), 100° (40), and 110° (9) and was not adjustable. This adjustability in the study of Kashif et al. was from 100° to 120° (16). These differences were due to used standards in these studies.

The desk angle in this research was considered 0°, which is in line with Thariq et al.'s study (8) and is different from the study of Taifa and Desai that reported this angle as 0° to 20° (9). Also, in the study of Khanam et al., this angle was considered as 10 degrees, which is different from the current study (40).

5.1. Conclusions

An ergonomic chair with adjustable parts was designed to achieve a good match between anthropometric characteristics of students and used furniture. The size of the chair was based on anthropometric dimensions of students. Since most activities of students are done while sitting on the chair, the ergonomic design of the chair is important for students. Thus, taking action to correct the existing chairs is important in terms of physical health of students and economic sentiment as physical problems associated with improper sitting conditions would lead to financial and medicinal costs.

The chair designed and developed in this study was ergonomic and helped to reduce musculoskeletal disorders in students. Some ergonomic characteristics of this chair included adjustability of footrest, backrest, armrests, and desk and these factors led to the use of this chair by many students with different body sizes. The edges of the seat had a curvature that prevented pressure to different parts of the body and created comfort for users. Other advantages of this chair that distinguished it from other educational chairs include adjustable footrest so that legs can be fully fitted, adjustable height of desk and left armrest, desk rotation in two axes of X and Y, adjustability of angle between the backrest and seat in four degrees, large surface of the desk, grooves on the backrest to place bags, a groove on the desk to place pens and pencils.

One of the limitations of this study was the inability of seat height adjustment and lack of angle adjustability in the desk, which are technical limitations in constructing the chair.

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