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Student's Body Dimensions in Relation to Classroom Furniture

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ABSTRACT

Background: This study was carried out to investigate the fit between university student's anthropometry and classroom furniture dimensions.
Method: In this cross-sectional and descriptive-analyzing study conducted in 2012, a total of 194 students (aged 18 through 30 years), were recruited randomly from Tabriz University of Medical Science community. The body size of each student was assessed using anthropometric measurements including shoulder height, elbow height, popliteal height, buttock-popliteal length, hip breadth and distance between elbows. Combinational equations defined the acceptable furniture dimensions according to anthropometry and match percentages were computed, according to either the existing situations assuming that they could use the most appropriate of the sizes available.
Results: Desk and seat height were higher than the accepted limits for most students (92.5% and 98.4%, respectively), while seat depth was appropriate for only 84.6% of students. The data indicate a mismatch between the students' bodily dimensions and the classroom furniture available to them. The chairs are too high and too deep and desks are also too high for the pupils. This situation may have negative effects on the sitting posture of the students especially when reading and writing.
Conclusion: High mismatch percentages were found between furniture and students' anthropometry. The results confirm that furniture for university students should be selected and designed busied on their anthropometric dimensions.

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Introduction

It is estimated that 70–85% of individuals experience Low Back Pain (LBP) during the course of their lives[1]. An onset of LBP is expected to occur at the mean age of 30 and peaking in occurrence between the ages of 45 and 60 years[2]. However a recent European survey of LBP reported that the 6-month prevalence in 17–25 year age group seems to be similar to older age groups[3]. In the general population, LBP prevalence rates are known to increase over the adulthood period[4,5].

Sit related Musculoskeletal Disorders (MSDs) are frequent and several studies[6,7] have pointed out an association between back pain and prolonged sitting. Students spend about 84% to 88% of their time in the sitting position[8]. 41.6% of students experienced pain while sitting in the classroom and 69.5% of the back pain occurred after 1 h of sitting and increases with the duration of the sitting position at school[9]. Some studies have shown a positive relationship between back pain and seat height[10]. University students constitute a large group of people who spend a lot of their time on the university chairs and desks in a static or awkward posture[11]. High prevalence of neck and upper extremity complaints among university students has been reported in the literature[12].

During class time, students sit in poor postures with trunk, back and neck flexed[13]. The students should be included in ergonomic design programs to be prevented from MSDs suffering[14]. Students sitting posture can be influenced by several factors such as the anthropometric dimensions of the students and design features of classroom furniture. Therefore, the mismatch between the students' anthropometry and furniture design can be one of the risks of MSDs[10]. Recent developments in ergonomics have heightened the need for good chair design. Since the 1970s, concerns with school seating have continued to provide incentive for publications[15,16]. There have been several studies in school children anthropometry. Most of the studies have only been carried out in age grouped 6 through 14 years old[8, 17].

So far, there has been little attention to the design of university furniture, because the researchers believe that using furniture that promotes ergonomic (appropriate) postures in childhood is more important than using it in adulthood. The main reason of this matter is that the sitting habits are formed at this young age and it will be too difficult to change them in adulthood[10]. Thus, the anthropometric data used in the design of the equipment for Iranian higher education are based on anthropometric data from other countries and it is necessary to collect related data to support ergonomic design from Iranian population. To our knowledge, a few studies have been done on university students and mismatch between their anthropometry and class chairs in Iran[6,8,18,19]. Although these studies have investigated mismatch between the anthropometric features and classroom furniture dimensions in schools and universities, they did not consider the mismatch between arm rest distance and elbow distance.

Therefore this study was conducted to investigate any mismatch between furniture features and body dimensions of the students with especial consideration on arm rest distance and elbow distance.

Materials and Methods

This study was cross-sectional and descriptive-analyzing conducted in 2012. According to result of Roscoe[20] (1975) study with a sample size between 30 and 500 is adequate for most research. Therefore sample for the study comprised 194 students (120 females and 74 males) that were randomly selected from Tabriz University of Medical Science community. Sampling frame was according to the list of students` name which was available through the education section of the university. Sampling was done with considering to the students` frequency in academic level (bachelor, master of sciences or PhD), age and fields. To determine the sampling volume, preliminary study based on a pilot study consisting of 12 of volunteers was done according to the effect size. Based on the mean and standard deviation of measured parameters, with 95% Confidence Interval (CI) and tolerated error 2.5% around the mean, sample volume for different parameters is gained. The biggest sample volume was calculated for sitting elbow height parameter SELH parameter. So the sample volume was 174 (Mean=24.06 and SD= 4.04).

For volunteer's selection considering with the above features, sampling was extracted by simple random method from the list. For random numbers, MS EXCELL version 2007 was used. The age of range of the subject was from 18 through 30 years (mean =23.3 years, SD=3 years). All subjects were healthy, engaged in average levels of physical activity, and had reported no occurrences of MSDs for at least the year preceding the study (which was defined as never having seen a physician, physiotherapist, chiropractor, or other healthcare professional for MSDs), and had never been absent from work because of MSDs. Each subject was then informed of the risks and benefits of participation in this study and informed consent obtained from all subjects. Approval for this work was obtained from the ethics committee of the Tabriz University of Medical Sciences and all of the experiments were carried out at Ergonomics Laboratory of the university.

In addition to demographic information including age and gender, the following 10 body dimensions which are essential for seating and work surface design[12] were measured in this study [Fig. 1]. The measurement instruments included anthropometric station measuring tape, a wooden right angle and a mechanical column scale (Detecto) with eye level rider to measure weights (with more than 50 g accuracy).

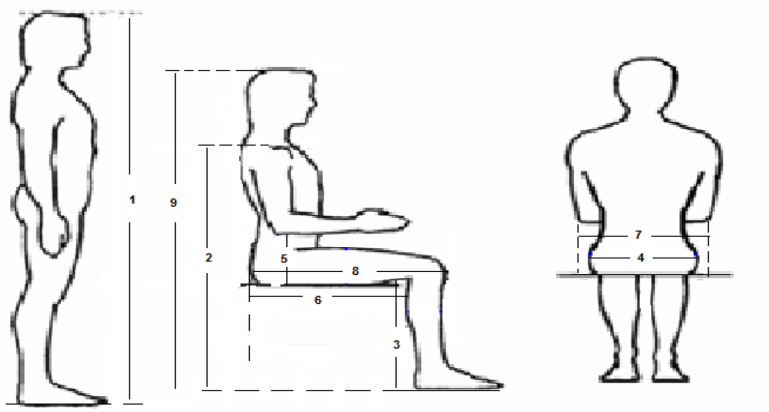

Fig. 1: anthropometric measures: 1) stature, 2) sitting shoulder height., 3) popliteal height., 4) buttock width., 5) sitting elbow height from seat pan., 6) buttock- popliteal length., 7) distance between elbows , 8) buttock- knee length., 9) sitting height (modified from Dianat et al. 2012)

For the furniture measurements, only one style of chair with no mounted desktop and one style of desk were identified as the dominant model in the students' classroom. The critical dimensions of current university furniture (chair and table) was as follows: seat height from the floor (47.2 cm), seat width(44.4 cm), seat depth (43.9 cm), backrest height(89.7 cm), desktop height from the seat pan (31.9 cm) and distance between armrests (44.3 cm).

Prior to measurements, the investigator checked that the participants had light cloths, empty pockets, and wearing no shoes. Anthropometric measurements were taken while each student was sitting on the adjustable chair of fixed height with knee and elbow bent at 90°, the feet placed on the floor and straight looking forward.

Relationships between school furniture dimensions and body dimensions

There have been some equations, to investigate the mismatch between classroom chairs and anthropometric dimensions of students. To compare and investigate any existing mismatch, the following dimensions of subjects (Table 1) and the classroom furniture (Table 2) were obtained.

1) *Seat height and popliteal height mismatch:*

Based on references, the seat height should be adjusted according to the popliteal height[21]. Besides the knee angle in to the vertical axes should be up to 30°[22]. But the minimum of the same angle was 5°. So, the design could be done in following interval:

$$(PH+2)\cos 30° \leq SH \leq (PH+2)\cos 5°$$

Where SH is seat height and PH is popliteal height.

Table 1: Anthropometric dimensions and their descript

Dimensions	Description
Stature	The vertical distance from the floor to the vertex (i.e. the crown of the head).
Sitting height	Vertical distance from the sitting surface to the vertex (i.e. the crown of the head).
Sitting elbow height from seat pan	Vertical distance from the seat surface to the underside of the elbow.
Buttock-knee length	Horizontal distance from the back of the uncompressed buttock to the front of the kneecap
Buttock-popliteal length	Horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meet the underside of the thigh
Popliteal height	Vertical distance from the floor to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into the lower leg
Buttock width	Maximum horizontal distance across the hips in the sitting position
Sitting shoulder height	Vertical distance from the seat surface to the acromion (i.e. the bony point of the shoulder
Distance between elbows	The horizontal distance between the end bony point of one of the elbows to the same point of the other one, when the elbows are in right angle and touch the sides of the body.

Table 2: Components of chair dimensions and its description

Dimension	Description
Seat height	Vertical distance from the highest point on the front of the seat to the floor
Seat width	The horizontal distance between the lateral edges of the seat.
Seat depth	The vertical distance from the back of the sitting surface of the seat to its front edge.
Backrest height	The vertical distance from the sitting surface to the top edge of backrest.
The distance between armrests	The vertical distance between two internal edges of the armrests.
Desktop-seat height	The vertical distance from the sitting surface to the upper edge of desktop.

2) Seat width and buttock width:

According to the literature, the seat width should be designed based on the largest buttock width[23]. The minimum number for seat width is obtained from multiplication of 1.1 by the buttock width and for the maximum, the coefficient is 1.3. So, the proposed interval for seat width design is:

$110\%\ BW \leq SW \leq 1130\%\ BW$

Where SW is seat width and BW is buttock width.

3) Seat depth and buttock- popliteal length:

It is believed that the seat depth should be designed for the 5th percentile of the BPL distribution[24,25]. Some other studies confirmed that it should be at least 2 inches shorter than the BPL[26]. However, the most famous reference that upheld a mismatch for seat depth has been defined as all the numbers which exist in following equation is Parcells et al in 1999:

$0.8\ BPL \leq SD \leq 0.95\ BPL$

Where BPL is buttock- popliteal height and SD is the seat depth.

4) Backrest height and sitting shoulder height:

For facilitating the mobility of the torso and arms towards the lower body, it is better to design the backrest height up to the sub-scapula height[23,25]. So, the subsequent interval was proposed to determine the backrest height of the classroom furniture:

$0.6\ SH \leq BH \leq 0.8\ SH$

Where BH is backrest height and SH is shoulder height.

5) *Desktop-seat height and sitting elbow height:*

The elbow height is recommended as the original determination for desktop height[22,18]. Some researchers suggested that the desktop height should be 3 to 5 cm higher than the sitting elbow height[12,17,24].

SELH ≤ DH ≤ SELH +5

Where SELH is sitting elbow height and DH is desktop height.

6) *Distance between armrests and distance between elbows:*

According to the literature, the distance between armrests should be 18 inches (BIFMI Guideline) or might be 16.5 to 19 inches in some other guides. In this study we proposed a new interval, equivalent to seat width equation. So, we defined the minimum and maximum distance between armrests as the follow:

110% ELELD ≤ AD ≤ 1130% ELELDW here ELELD is distance between elbows and AD is distance between armrests.

Data treatment and analysis

Data analysis, using SPSS for MS Windows 7.0, involved the computation of descriptive statistics (mean, standard deviation, max, min and 5^{th} and 95^{th} percentiles) to describe the physical characteristics of the subjects. Data distributions were tested for normality using the Skewness test. Anthropometric measures of each participant were compared to the relative furniture dimensions using EXCEL in order to identify a match or mismatch between the specific student and the furniture that he/she were used. Based on existing research[27,28], a mismatch is defined as incompatibility between the dimensions of the classroom furniture and the dimensions of the student's body.

In this investigation, one source of error is the technical errors that hidden in measurement instruments[29] and measurement errors. To control measurement instruments errors, calibration of the tools has been done. But to eliminate the intra-evaluator errors, all of measurements performed by the same investigator in the same subjects and to verify and enhance the accuracy of the measurements (inter-evaluator), each measurement repeated two times from the same subjects and the average of the two were chosen as a mean value. All measurements were done by the first author of this paper.For scale reliability analysis, interclass correlation coefficient was calculated. Consistency reliability was approved in all cases. ICC was more than 0.7 for every volunteer.

Results

Demographic and anthropometric characteristics of subjects are shown in Table 3. The minimum and maximum values for popliteal height were 32.3 and 65.4 cm, for popliteal–buttock length were 32 and 57.3 cm, for shoulder height were 63.4 and 121.2 cm, for the elbow–seat height were 16.82 and 47.30 cm, for the buttock width were 31.3 and 43.12 cm, for distance between elbows were 27 and 47.07 cm, respectively (Table 3).

Table 3: Demographic and anthropometric characteristics of subjects

DIMENSION	MIN	MAX	MEAN	SD	5^{th}%tile	95^{th}%tile
Age(yr)	18	30	23.34	2.98	20	29
Weight(kg)	39	168	63.47	15.97	46.27	86.82
Stature(cm)	143	188	167.54	9.057	155.87	184
PH(cm)	32.3	65.4	40.24	4.31	35.07	45.87
BPL(cm)	32	57.3	45.31	3.62	40.25	51.10
BKL(cm)	43	65.40	56.29	5.64	49.90	63.17
SH(cm)	114.8	143	126.17	9.61	116.65	138.40
SELH(cm)	16.82	47.30	23.47	3.21	19.27	28.05
BW(cm)	31.3	43.12	36.20	2.32	32.44	40.41
ELELD(cm)	27	47.07	36.96	3.52	30.85	43.04
SHH(cm)	63.4	121.20	100.71	6.33	91.55	110.52

The result of collected data about the classroom furniture dimensions and obtained body dimensions are summarized in Table 4. As it can be seen from this table, shoulder height (with backrest height), distance between armrests, buttock-popliteal length, popliteal height and elbow height from seat pan in sitting position were the common mismatch between the body dimensions of students and the dimensions of classroom furniture.

Table 4: The percentage of mismatch between body dimensions and furniture dimensions according to gender.Less than normal: body dimension was above the upper limit of the design interval. More than normal: the body dimension was below the lower limit of the design interval. Normal(fit): body dimension was in design interval

Dimensions	Less than normal (%)		Normal (%)		More than Normal (%)	
	M	F	M	F	M	F
Desk height(cm)	2.7	0	16.2	7.5	80.3	92.5
Distance between armrests(cm)	29.7	3.3	67.6	71.7	2.7	25
Seat height (cm)	1.3	0.5	10.8	1.6	87.9	97.9
Seat width(cm)	5.4	4.1	51.4	75.9	21.6	21
Seat depth (cm)	1.3	1.3	69	15.4	29.7	83.3
Backrest height(cm)	0	0	29.7	2.5	70.3	97.5

Discussion

The aim of the current study was to evaluate the match between dimensions of the classroom furniture in universities with student's body dimensions. The result of this study showed considerable mismatch between students` body dimensions and classroom chairs.

One of the important findings of current study was that the backrests of chairs were too high. Consequence of using high backrest may be forward head inclination, uneven shoulder, kyphosis, scoliosis and lordosis[11]. The degree of forward head and neck flexion, combined with the static nature of desk tasks, appears to be related to the incidence of neck and/or shoulder complains[44]. Anthropometric dimensions are very important for designing university furniture[15,30], because proper posture is a critical factor for prevention of musculoskeletal disorders[31].

The university students spent long periods in sitting position, so they may suffer from improper designs of furniture. Then designing and applying proper furniture may reduce fatigue and discomfort in the sitting posture[30].

Seat height mismatch

According to the current study, the seat height only matched to 10.8% of males and 1.6% of females, which are obviously greatly below the lower limit of the acceptance range (Table 4). In other words, subjects are sitting on seats that are too high for them. According to filed observations most of subjects sitting with their legs not touching the floor. These positions can place high amounts of stresses on the popliteal arc that runs through the underside of the thigh and may cause serious discomfort and possibly risk injury. This may lead to an increase in tissue pressure on the posterior aspect of the thighs.

One study[32] indicated that the tension in the lumbar and trapezius muscles was significantly reduced among students when the seat height was match to their popliteal height. Toomingas and Gavhed demonstrated that optimal seat height may contribute to less frequent neck/scapulae and back pain. Since the mismatch forces students to slide forward on the seat of the classroom furniture, therefore seat height match appears to be necessary[33].

Seat depth mismatch

Seat depth mismatch with thigh length creates strong stresses on the thigh. The mismatch between the subject's popliteal–buttock length and current seat depth totally was 57.8%, which is well beyond the upper limit of the acceptance range for the current seat depth. A too shallow seat may cause the user to have the sensation of falling off the front of the chair as well as result in a lack of support of the lower thighs[27]. On the other hand, too deep chairs force students usually place their buttocks forward on the edge of the seat, especially while reading and writing. Consequently, in this position they could not use the back rest properly. As a result, the lack of back support causes a slumped, Kyphotic posture[11].

Backrest height mismatch:

A good back rest, fitting the natural spinal curves, stabilizes the spine[34], facilitates lumbar lordosis[35] and reduces Kyphotic postures[34]. A backrest contributes to carrying the weight of the body, and keeping disk pressure in low level by supporting lumbar. However, the result of present study expressed that backrest height is acceptable for about 29.7% in males and 2.5% in females. It means that in more than 83.9% of subjects, shoulder height is below the lower limit of the acceptance range. Studies have shown that sitting in a normal stenographic type of chair with no back support increases the flexed posture of the lumbar spine. Consequently, the compressive forces on the lower back increase. So a variety of designs of school furniture are being promoted for the improvement of posture and/or motility[22].

Desk height mismatch

According to our finding, 88.1% of subjects had a mismatch between desk height and their elbow–seat heights. For majority of subjects the elbow-seat height was much smaller than the lower limit of acceptance for the height of the provided desk. When the elbow rest height is lower than the desk or table surface, the working arm must be raised. For compensating, shoulders must also be raised or abducted placing a stress on the deeper posterior neck musculature to provide stabilization of the head posture. In addition if the weight of the head is not properly supported, it can cause discomfort and risk of injury to the neck and shoulders[36]. As the elbow-seat height for a few present of student was higher than desk height so it may force user to bend forward, with the body weight being supported by the arms. Eventually Kyphotic spinal posture with round shoulders is created. The head also moves forward (more than 30° from the vertical position), increased activation of the neck musculature occurs, which increases the probability of fatigue, because a static posture is maintained by the neck muscles[37]. Therefore improper design and mismatch of desks and chairs lead to an imbalanced and more Kyphotic posture of lumbar spine and require more muscle control to maintain the upright stability and sitting posture[16, 38].

Seat width mismatch

An important element in the magnitude of the pressure under the buttocks is the form of the supporting surface[39]. Some investigators have recommended that the seat width should be at least 45 cm, or 5 cm wider than the hip breadth[40,42]. Another recommendation is that d a seat width should be equivalent to 99 percentile value plus 15%[22]. The breadth of sitting surface is determined according to the 95% percentile values of hip breadth[26].

The mismatch between seat width and buttock width could be seen in 25.55% of students. Consequently the least mismatch existed in this dimension. The seat should be wide enough to accommodate a user's hips and clothing, and comfortably allow use of the armrests. There is a need that a reasonable proportion of the population of potential users can easily get up and sit down and be satisfied with their seat design[41,43]. The anthropometric measure width of the hips should be lower than what should be allowed for width of the seat. There must be added, on each side, an extra width for movement of the arms if the seat is equipped with armrests.

Distance between armrests and distance between elbows

Armrests help relieve neck, shoulder, and back stress. It can provide good surface area for the arm to contact so that pressure between an arm and armrest is minimized. It also should be adjustable up and down, as well as in and out. This allows for more customization and better control of comfort. For many tasks, arm support reduces upper body fatigue, allows for easier shifts in body position, and makes it much easier to enter and exit the chair. Armrests should be adjustable in height, width and depth to comfortably support the forearms or elbows while sitting with relaxed shoulders[14].Most of investigator[6,8,18,27]demonstrated mismatch between some dimensions of furniture; however none of them mentioned mismatch between elbows distance and armrests distance. The result of current study showed in total 30.35% mismatch between armrests distance and elbows distance. So that 69.7% subjects` distance between elbows were placed in design interval. Armrests should not limit access to the work surface, because body flexion will be decreases and stress in the knee and hip joints during sitting-to-standing transitions will be reduced[15].

Conclusion

Overall these findings confirmed that the majority of students had mismatch with university furniture. By obtaining more anthropometry data in variety age groups and generalizing it to any educational place may help design of ergonomic furniture. As developing comfortable posture, educational furniture should also support the learning activities of the students. Therefore school furniture should be able to facilitate learning by providing a comfortable and stress-free workstation. Using ergonomic chairs based on collected data from educational place could help us to prevent discomfort, inappropriate sitting postures and occurring musculoskeletal disorders, conclusively increasing efficiency in schooling situations.

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Competing interests

The authors declare that there is no conflict of interest.

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