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Evaluation of Classroom Furniture Design for Ecuadorian University Students: An Anthropometry-Based Approach

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A B S T R A C T

It is widely known that students' exposure to poor postures due to inappropriate classroom furniture design may contribute to the increase of the prevalence of musculoskeletal disorders symptoms that if not identified on time could lead to severe health issues. In this context, due to the unavailability of scientific studies related to this topic in Ecuador, the aim of this research is twofold. The first aim was to define the classroom furniture design parameters' dimensions for university students according to relevant anthropometric information. The second aim is to conduct a preliminary diagnostic of the appropriateness of classroom furniture currently used in Ecuadorian universities to students' anthropometric characteristics. The obtained results are particularly relevant as the ten design parameters here proposed could be the starting point to the creation of a specific Ecuadorian standard to regulate classroom furniture design for university students. That would ensure domestic and foreign manufacturers could offer furniture more secure and adequate to the anthropometric characteristics of the university population of Ecuador. On the other hand, the preliminary study found evidence that all the examined classroom furniture presented mismatches in at least five design parameters, and students exposed to them over the past twelve months had a high prevalence of symptoms of musculoskeletal disorders in the hips, back, thighs, and neck.

1. Introduction

Anthropometry is the sub-branch of physical anthropology that studies the measurements of the human body in terms of the dimensions of bone, muscle and adipose tissue [1]. These measurements are vital for proper workstations design to prevent musculoskeletal disorders in the workforce [2,3] and at the same time, to facilitate the performance of labor activities with higher productivity [4,5].

Consideration of anthropometric information in classroom furniture design allows students to acquire higher levels of comfort [6], to reduce the presence of musculoskeletal disorders [7−11] and to facilitate the understanding of the knowledge imparted [12,14].

From the ergonomic point of view, three principles of design are known for the application of anthropometric information: the design for the average individual, for extreme individuals, and for an adjustable interval [15]. The latter has been the most suggested by researchers in the design of school furniture [16−18], however, it is the least feasible from an economic point of view. From a technical perspective, the first one mentioned is the least recommended design principle as it guarantees comfort only for 50% of the population.

In general, the design principle for extreme individuals has been the most used in classroom furniture design [17]. It is based mainly on the idea that if the most relevant dimension of the design is suitable for extreme cases (5th or 95th percentile of the corresponding anthropometric measure), then it will guarantee comfort to the majority of the population.

Under this last principle of design, numerous international studies have identified discrepancies between the dimensions of classroom furniture and the anthropometric measures of its target audience: students of basic education [17,19−21], upper secondary education (between 15 and 18 years) [22, 23]; and university students (between 18 and 30 years) [24].

The few Ecuadorian studies that analyze ergonomic or anthropometric principles for school furniture design, do so for

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boys and girls in preschool education [25] or students at the levels of Basic Education [26]. In the latter case, work for children with motor impairment [27,28] stands out. In national scientific literature, studies that address this subject for university students are even scarcer.

The use of inappropriate classroom furniture is one of the causes that favor students in adopting poor postures while performing intraclass academic activities [14–16]. Some studies have concluded that when these postures are sustained over a long period of time, it is considered a risk factor in the development of musculoskeletal disorders [7,22,23].

Musculoskeletal disorders comprise a wide variety of degenerative and inflammatory diseases in the locomotor apparatus [29]. They are characterized by concomitant and non-concomitant symptoms that comprise pain caused by inflammation, paresthesia, strength loss, fatigue, and difficulty or incapacity to perform certain movements [30,31]. This group of injuries occurs more frequently in works that require important physical activity, weight carrying, repetitive movements, application of forces and as a consequence of bad postures sustained over long periods of time [32].

In order to detect the prevalence of musculoskeletal disorders symptoms (MDS), the Nordic Musculoskeletal Questionnaire (NMQ) designed and validated by Kuorinka [33], has been an instrument of extended use in the context of ergonomic or occupational health studies [29,30,32,34–36]. It allows the identification of initial symptoms, which have not yet triggered diseases or have not yet led the affected patients to consult the doctor. Consequently, its value lies in providing information that makes it possible to proactively estimate the level of risks and avoid exposure to them through corrective measures.

The unavailability of anthropometric databases in Ecuador for adults could imply that the classroom furniture currently in use by students in universities may not be in accordance with their anthropometric characteristics. According to this, their exposure to classroom furnishings for a long period of time could increase the prevalence of MDS, which could lead to serious musculoskeletal disorders and its irreversible consequences if not detected on time.

In this context, this paper aims to define standards for the design parameters of classroom furniture for university students in Ecuador, in accordance with relevant anthropometric information. Based on these standards, classroom furniture used in a sample of universities in Guayaquil is evaluated. In addition, MDS prevalence is measured in students who use such furniture in their daily academic activities and also possible risk factors are inquired.

2. Methods

For school furniture design, the anthropometric measurements considered relevant in this study are presented in Figure 1.

2.1. Anthropometric information

There are no official anthropometric databases in Ecuador. However, Lema-Barrera [37] made precise estimates of anthropometric measures selected for the 5, 50 and 95 percentiles of the adult Ecuadorian population of both sexes and self-identified according to three ethnic origins: afro-Ecuadorians, indigenous and mestizos. This secondary information was used as the basis of calculation in this research. The mean and standard deviation values of these measures are presented in Table 1.

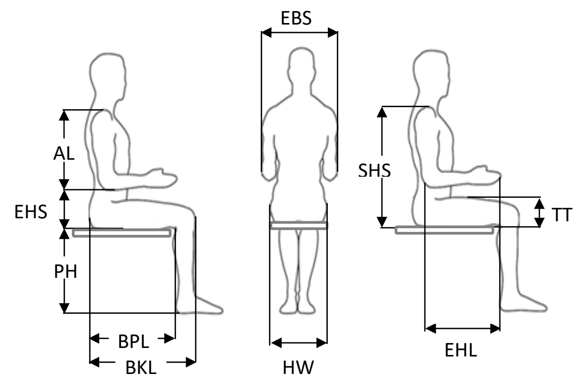

Figure 1: Relevant anthropometric dimensions for school furniture design: Arm length (AL); Elbow height sitting (EHS); Popliteal height (PH); Butock-knee length (BKL); Buttock popliteal length (BPL); Elbow breadth sitting (EBS); Hip width (HW); Shoulder height sitting (SHS); Elbow-hand length (EHL); Thigh thickness (TT).

Table 1: Population mean and standard deviation (mm) of selected anthropometric measures for Ecuadorian men and women per ethnic group

Parameters	Mestizos		Indigenous		Afro-Ecuadorians	
	M	F	M	F	M	F
AL	363 (17.0)	347 (27.5)	371 (34.6)	330 (23.4)	390 (25.9)	341 (26.5)
EHS	232 (29.6)	235 (27.9)	220 (66.2)	231 (25.6)	209 (19.7)	225 (20.7)
PH	415 (30.4)	386 (30.2)	415 (34.5)	396 (41.6)	486 (27.9)	404 (28.5)
BKL	571 (36.0)	541 (31.6)	552 (31.7)	527 (34.2)	584 (26.8)	531 (27.3)
BPL	464 (38.6)	437 (27.4)	461 (15.6)	433 (33.7)	493 (24.8)	429 (29.5)
EBS	447 (40.6)	400 (40.3)	448 (62.8)	456 (30.7)	499 (21.4)	388 (34.6)
HW	356 (25.1)	356 (26.3)	379 (30.2)	391 (32.0)	406 (18.9)	361 (25.7)
EHL	503 (23.9)	466 (30.6)	503 (32.3)	448 (30.4)	524 (28.0)	476 (23.2)
TT	132 (19.7)	124 (17.4)	131 (20.5)	123 (19.6)	153 (12.8)	122 (09.7)

Note: Mean (standard deviation). Source: Adapted from [38].

Anthropometric measurement values of the Ecuadorian population are very heterogeneous [37]. According to this, it is important to define an approach strategy to guarantee comfort to 95% of people who could use school furniture. For this reason, this study will consider the measures of the biggest ethnic group in Ecuador. In this respect, according to the results of the 2001 and 2010 national censuses [38,39], mestizos represent the largest percentage of the population in Ecuador as shown in Figure 2.

To estimate extreme values for each relevant anthropometric measurement, the 5th percentile of the sex with the lowest dimension and the 95th percentile of sex with the highest were taken among the mestizo population.

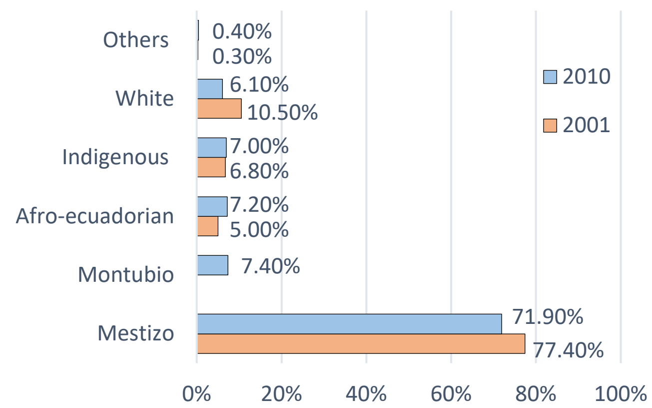

Figure 2: Ethnic self-identification in Ecuador according to 2001 and 2010 national censuses

2.2. School furniture design parameters

This section presents the mathematical formulae to estimate the design parameters of classroom furniture considering the casuistically relevant anthropometric measures and the biomechanics of the individual in a sitting position.

As an example, Figure 3 shows the design parameters of school furniture composed of a table and a chair. However, in Ecuadorian universities, it is also common to find chairs with mounted desktop.

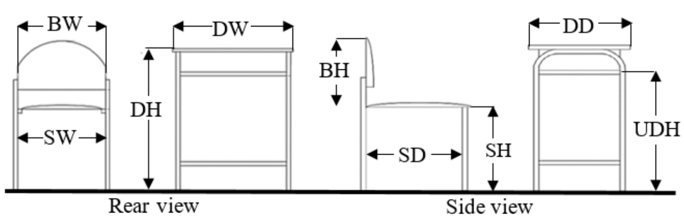

Figure 3: Representation of classroom furniture design parameters: Backrest width (BW), Seat width (SW), Seat height (SH), Backrest height (BH), Seat depth (SD), Desk height (DH), Desk width (DW), Desk depth (DD) and Under-desk height (UDH).

Traditionally seat height (SH) has been related to popliteal height (PH), which is measured from the ground to the popliteal fossa of the person sited with erected trunk [40]. The human being, when sitting, does it on the ischial tuberosities, which are bony structures that morphologically do not allow to maintain the balance of the body in this position [41]. To achieve such a balance, support is required in the back and feet. The seat height, on the other hand, must be shorter than popliteal height so that legs can lean forward between 5° and 30° regarding the vertical axis of the body [22]. These biomechanical considerations are considered in (1), where CC is a footwear correction.

$$(PH + CC)\cos 30° \leq SH \leq (PH + CC)\cos 5° \qquad (1)$$

This equation has been widely used in research aiming to find an eventual mismatch between classroom furniture and the anthropometric characteristics of students who regularly use them [4,11,17,19,21,22]. In this study the 5th PH percentile for mestizo women was used and a CC value equivalent to 20 mm.

According to ISO 9241-5: 1998, the seat width (SW) should be longer than the hips width (HW) of the person while seated to facilitate the adaptation of the chair to the changing needs of the individual [42]. In this regard, (2) has been regularly used in analogous researches [4,22] and implies that the appropriate seat width should vary between 10% and 30% of HW. Specifically, in this study, the 95th percentile of the hip width of mestizo women was used.

$$1{,}1HW \leq SW \leq 1{,}3HW \qquad (2)$$

ISO 9241-5: 1998 establishes that the adequacy of seat depth (SD) is achieved when it is shorter than the user's popliteal-buttocks length (BPL) [42]. This relays on the idea that the popliteal fossa should be free to ease blood supply to the legs. Consequently, some researchers have agreed that the appropriate dimension for SD should lie within the interval of 80% to 95% of BPL [5,11,20-22] as shown in (3). In this study, the 5th percentile of mestizo women's BPL was employed.

$$0{,}80\ BPL \leq SD \leq 0{,}95\ BPL \qquad (3)$$

Some authors suggest that upper backrest height (BH) should measure between 60% to 80% shoulder height (SHS) to ease mobility in the upper trunk [11,17,21,22]. The secondary anthropometric information available does not include data from this measure. However, since the SHS matches the sum of the arm length (AL) and the elbow height of the person in a seated position (EHS) according to [41], an equivalent form of calculation is presented in (4). There, EHS represents the 5th percentile of men and AL the 5th percentile of women.

$$0{,}6(EHS + \mathrm{AL}) \leq BH \leq 0{,}8(EHS + \mathrm{AL}) \qquad (4)$$

The seatback width (BW) has not been widely discussed in the literature as noted in [17]. However, some authors have come to the agreement that for BW the width of the hips (HW) can be considered the relevant anthropometric measure [16,18]. In this regard, we decided BW be longer than the 95th percentile of HW for mestizo women, as shown in (5).

$$BW \geq \mathrm{HW} \qquad (5)$$

The under-desk height (UDH) must allow the sliding of the user seated towards the interior of the table. Thus, the ideal measurement should include seat height, seated thigh thickness (TT) and clearance (20 mm) to facilitate the change of posture of the legs in this position. These considerations are included in (6). Here, TT corresponds to the 95th percentile for men and PH to the 5th percentile for women.

$$(PH + CC)\cos 30° + TT + 20 \leq UDH \leq (PH + CC)\cos 5° + TT + 20 \qquad (6)$$

For desk height (DH) estimation, previous research has taken into account the biomechanics of the shoulder and have considered acceptable flexion angles from 0° to 25° and abduction angles between 0° and 20° for this joint [4,5,11,21]. Such authors have used (7). However, in the absence of SHS measurements and considering it equivalent to the sum of EHS and AL, the above expression can conveniently be converted to (8), which was used in this research to determine the match standard for DH. In this case, PH and AL correspond to the 5th percentile for women, while EHS corresponds to the 5th percentile for men.

$$EHS + [(PH + CC)cos30°] \leq DH \leq [(PH + CC)cos5°] + 0{,}8517EHS + 0{,}1483SHS \quad (7)$$

$$EHS + [(PH + CC)cos30°] \leq DH \leq [(PH + CC)cos5°] + EHS + 0{,}1483AL \quad (8)$$

According to [19], the design of the table depth (DD) and the table width (DW) have been sparsely discussed in the literature. Table depth is important to provide enough space for the user to change the posture of the lower part of the body. Thus, we consider that this dimension should exceed the 95th percentile of men knee-to-back length (BKL). This assumption is also true for the tablet length (TL) in chairs with mounted desktops. Consequently, the lower limit of these two design parameters will be estimated through (9).

$$DD \geq BKL \quad (9)$$

The width of the table (DW), on the other hand, should allow the users to rest their two forearms on the surface at the same time, whether they are upright or abducted in a relaxed posture. In this case, some authors have considered theoretical reference positions with a shoulder abduction angle between 0° and 20° [5,20,21]. Thus, in this study it was considered that the minimum acceptable table width should include: the length from elbow to elbow of the person while seated (EBS) corresponding to the 95th percentile of men, the distance that produces the abduction of the shoulders on the plane (equivalent to 2ALsen20°) considering the 95th percentile of AL for women and a 20 mm slack on each side as in (10).

$$DW \geq EBS + (0{,}684AL) + 40 \quad (10)$$

In addition to individual tables and chairs, Ecuadorian higher education institutions usually tend to purchase chairs with side-mounted desktop as classroom furniture. However, despite being so common, scarce attention has been given in the scientific literature to the ergonomics of its design [16]. All chair design parameters mentioned in this section are equivalent to those used in side-mounted desktop chairs (SH, SW, SD, BW, and BH). Similarly, the anthropometric criteria considered above for the design of the desk height (DH) and its depth (DD) correspond to those required for the design of tablet height for side-mounted desktop chairs (TH) and its length (TL), respectively. It is only necessary to specify a design criterion for tablet width (TW).

In this study, the minimum width of the tablet in chairs with side-mounted desktop should include half of EBS, plus the distance that implies the maximum acceptable abduction of the elbow at 20° as suggested in [4,5,11,21] and 20mm of slack. However, TW should not exceed the 95th percentile of elbow-hand length (EHL, which is measured from the elbow to the tip of the middle finger in a seated position), since it would make it difficult for the student to access and leave the seat. All these considerations are presented in (11).

$$0{,}5EBS + (0{,}342AL) + 20 \leq TW \leq EHL \quad (11)$$

2.3. Data collection

Having secondary dataset on relevant anthropometric measurements of the adult population in Ecuador at hand, the sampling strategy focused on measuring, on the one hand, the main parameters of school furniture design in Guayaquil universities, and on the other hand, the prevalence of possible musculoskeletal disorders symptoms (MDS) in students who use such furniture on a daily basis.

The sample size was calculated considering an infinite population with a confidence level of 95% and a margin of error of 4%. The resulting value was 601 individuals taking into account a proportion of successes and failures of 50%. Among the 13 functional universities in Guayaquil, 5 were randomly selected. Then, in each institution, five classrooms were selected through a simple random sampling. For each identified furniture model, ten measurements were made of each of the ten design parameters considered relevant by the study authors (as shown in Figure 3). Such measurements were made with the use of a flexometer tape. The arithmetic mean was the measure of central tendency used to characterize every furniture design parameter dimension.

Next, the NMQ was used to identify MDS prevalence in students as a consequence of an eventual mismatch between the school furniture and their anthropometric characteristics. Its application was made in a self-administered way to those students who were willing to collaborate anonymously and who were not involved in work relations to any company in the last twelve months.

The questionnaire consisted of two general questions. The first one evaluated the presence of any MDS (pain, discomfort or numbness) over the last year in nine body parts (neck, shoulders, elbows, hands/wrists, upper back, lower back, hips/thighs/buttocks, knees, ankles/feet). The second question identified whether the presence of MDS within the last year would have prevented the user from doing any of their everyday domestic or entertainment activities. The questionnaire also recorded the age, height, weight, sex, ethnic self-identification, laterality, study time in Higher Education and the average number of hours per week that students spent seated.

The weight and height of the students were also measured using a Tanita UM-076 scale and a SECA 217 stadiometer, respectively. This information was used to determine the body mass index (BMI) of every polled individual. The data collection was carried out between October 2018 and April 2019.

2.4. Statistical analysis

The information collected was processed using the statistical package IBM SPSS Statistics 22.0. The normal distribution of data for age, height, weight, study time, sitting hours per week, and students' body mass index was measured using the Kolmogorov-Smirnov test with correction of significance of Lilliefors to a significance level of $p < 0.05$. The characteristics of participants were presented as proportions or percentages in the case of categorical variables and the mean and standard deviation for normal continuous variables. MDS prevalence differences for the k identified furniture models were assessed using the chi-square test at a significance level of $p < 0.05$.

Associations between MDS prevalence and some variables suspected of being risk factors (gender, laterality, age, BMI, number of hours per week seated, years of higher education and type of furniture) were measured using the Odds Ratio (OR) with a confidence level of 95%.

3. Results

Using the formulae presented in the previous section, the compatibility ranges for the ten design parameters for university school furniture were calculated and are provided in Table 2. These ranges, theoretically assure the proper comfort to 95% of the university student population self-identified as mestizo.

Table 2: Match intervals of school furniture design parameters for university students in Ecuador

Parameter	Lower bound (mm)	Upper bound (mm)
Desk height (DH)	509	603
Under-desk height (UDH)	510	560
Desk width (DW)	822	-
Desk depth / Tablet length (DD/TL)	630	-
Seat height (SH)	326	375
Backrest height (BH)	291	388
Seat depth (SD)	313	372
Seat width (SW)	440	519
Backrest width (BW)	400	-
Tablet width (TW)	411	500

From the above, it is clear that the ideal area for the seat should be between 0.138 m^2 and 0.192 m^2, the minimum surface area of the table should measure 0.518 m^2 and in the case of side-mounted desktop chairs, the minimum area recommended for the tablet is 0.259 m^2.

The ten design parameters were measured in nine models of furniture that are used in five universities in the city of Guayaquil. Among these, two universities are public (identified as B and D), and the three remaining are co-financed by the Ecuadorian government (A, C and E). University A and D employ a single type of furniture composed of individual tables and chairs. These have been identified as M1 and M6 respectively. University B uses two models, a side-mounted desktop chair (M2) and an individual table and chair station (M3). University C uses two different models of side-mounted desktop chairs (M4 and M5) and University E uses three of the same (M6, M7, and M8).

Table 3 shows the evaluation results of the nine types of furniture analyzed with respect to the computed compatibility ranges.

A second part of the study consisted of analyzing the prevalence of MDS in the student population that uses this furniture on a daily basis. For this, the NMQ was applied to a total sample of 672 students, however, only 628 questionnaires were valid, guaranteeing a real margin of error of 3.9%. The sample sizes according to the universities studied and the furniture models identified are presented in Table 4.

The majority of respondents identified themselves as mestizos (88.28%). 45.75% of the total were female and 54.25% male. 89.25% said they were right-handed and 10.75% were left-handed. The mean age was 21.45 years (SD=0.129 years). The mean height was 165.57 cm (SD=0.455 cm), the mean weight was 66.23 kg (SD=0.497 kg) and the mean BMI was 24.91 kg/cm2 (SD=0.535kg/cm2). On average, these students sat in their school furniture 21.22 hours a week during the last year of school (SD=0.448 hours) and the average length of stay in Higher Education was 33.49 months (SD=0.669 months).

Table 5 shows MDS prevalence according to its anatomical classification, for the study population. As might be noted, the highest annual MDS prevalence occurred in the neck, along the entire spine (upper and lower back) and in the hips/thighs.

In general terms, between 86.28% and 91.24% of university students who used these nine furniture models on a daily basis over the last year, felt musculoskeletal discomfort in at least one place in their body. More specifically, it can be affirmed with 95% confidence that between 59.78% and 67.34% suffered some discomfort in the neck; between 53.41% and 61.19% felt such symptoms in the upper back and between 50.66% and 58.48% in the lower back. It is important to notice that the lowest MDS prevalence was located in elbows with 21.83% (95% CI: 0.186-0.251).

Problems along the spine appear to have had a greater impact on the health detriment and well-being of students. The upper back ailments prevented 34.35% of them (95% CI: 0.306-0.381) from performing their usual activities in the last year. On the other hand, those discomforts related to lower back made it impossible for 37.56% of them (95% CI: 0.338-0.414) to perform their daily non-academic activities.

In detail, Table 6 shows the annual MDS prevalence differences for the 9 samples of students according to the model of furniture used in their daily academic activities. As can be appreciated, such differences are significant ($p<0.05$). This also shows that there is a relationship of dependence between the type of furniture and the presence of MDS in some parts of the body.

The neck-related annual MDS prevalence had a greater impact on students who used furniture model number eight (100% prevalence) and number five (88.24%), although this sort of prevalence was also relatively high for the remaining furniture models (greater than 50%) with the exception of the number nine. Particularly, those students who used furniture number five had a greater impact on their health. In fact, 48.53% of them were

Table 3: Match between school furniture and the ideal design parameters dimensions

Design parameters	A	B		C		D	E		
	M1	M2	M3	M4	M5	M6	M7	M8	M9
DH	730 [b]	660 [b]	720 [b]	660 [b]	760 [b]	721 [b]	671 [b]	721 [b]	761 [b]
UDH	590 [b]	640 [b]	670 [b]	631 [b]	731 [b]	670 [b]	650 [b]	700 [b]	740 [b]
DW	600 [a]		681 [a]			510 [a]			
DD/TL	320 [a]	450 [a]	391 [a]	300 [a]	300 [a]	360 [a]	300 [a]	350 [a]	300 [a]
SH	420 [b]	400 [b]	430 [b]	431 [b]	[b] 450	430 [b]	430 [b]	430 [b]	500 [b]
BH	250 [a]	350	320	211 [a]	310	250 [a]	180 [a]	190 [a]	280 [a]
SD	420 [b]	510 [b]	430 [b]	351	350	400 [b]	390 [b]	390 [b]	440 [b]
SW	400 [a]	510	430 [a]	450	440	510	410 [a]	410 [a]	411 [a]
BW	400	510	400	431	430	430	410	410	410
TW		390 [a]		250 [a]	300 [a]		300 [a]	300 [a]	300 [a]

Note: Non-superscripted values denote the design parameters that match ideal measures, a represents low mismatch and b refers to high mismatch. Cells in blank represents the absence of the parameter in the furniture.

Table 4: Sample size

University	Furniture	Sample	Total
A	M1	137	137
B	M2	89	120
	M3	31	
C	M4	37	105
	M5	68	
D	M6	105	105
E	M7	64	161
	M8	43	
	M9	54	

Table 5: Estimation of annual MDS prevalence and proportion of students unable to perform regular activities as a consequence of this prevalence

Anatomical classification of MDS	MDS prevalence over the last year	Impediment to carry out daily activities over the last year
Neck	0.636 ± 0.038	0.291 ± 0.036
Shoulders	0.466 ± 0.039	0.199 ± 0.031
Elbows	0.218 ± 0.032	0.120 ± 0.026
Wrists/Hands	0.324 ± 0.037	0.246 ± 0.034
High back	0.573 ± 0.039	0.344 ± 0.037
Low back	0.546 ± 0.039	0.376 ± 0.038
Hips/Thighs	0.432 ± 0.039	0.302 ± 0.036
Knees	0.275 ± 0.035	0.183 ± 0.030
Ankles/Feet	0.268 ± 0.035	0.151 ± 0.028

Note: 95% confidence intervals estimation

prevented from carrying out their usual activities during the same period given the presence of neck-related MDS in the last year. Students who used furniture five also showed a high prevalence of MDS associated with the shoulders (63.24%), wrists and hands (75%), lower back (63.24%) and hips/thighs (64.71%).In addition, students exposed to furniture number eight also showed high MDS prevalence in the upper back (65.12%), lower back (67.44%), hips/thighs (66.32%) and ankles/feet (65.12%). A similar analysis can be done for each group of students according to the model of furniture used in their academic activities.

Table 7 shows the OR values and their respective 95% confidence intervals for those categories of selected variables that could be associated with MDS prevalence. When the OR value is greater than one and its confidence interval does not include the unit, then the association under study is considered statistically significant [43]. In other words, it is ruled out that the association between the analyzed variable categories and the presence of MDS in any part of the body is given by chance.

4. Discussion

In this study, 10 classroom furniture design parameters for university students were determined based on secondary anthropometric information corresponding to the mestizo adult population of Ecuador. Such ideal dimensions, expressed in compatibility ranges, could assure comfort to 95% of the university student population self-identified as mestizo since this ethnic group represents the majority of the population according to the last two population and housing censuses as shown in Figure 1.

These results are particularly relevant in the context of the few academic or scientific studies on school furniture design for Ecuadorian university students according to anthropometric principles. Actually, to the author's knowledge, there is only one study related to this subject [44]. However, in that work, the use of anthropometric measures included in DIN 33402 standards [45]

Table 6: Annual MDS prevalence and annual MDS prevalence differences among students according to furniture models

	Model	Neck	Shoulders	Elbows	Wrists/ Hands	High back	Low back	Hips/ Thighs	Knees	Ankles/ Feet
MDS prevalence over the last year	M1	56.20	42.34	16.79	29.20	58.39	62.77	37.96	25.55	18.25
	M2	55.06	38.20	29.21	33.71	62.92	38.20	22.47	24.72	23.60
	M3	69.23	46.15	11.54	23.08	57.69	38.46	50.00	30.77	30.77
	M4	78.38	56.76	35.14	45.95	64.86	62.16	48.65	27.03	18.92
	M5	88.24	63.24	38.24	75.00	38.24	63.24	64.71	50.00	51.47
	M6	56.19	44.76	7.62	22.86	55.24	60.00	37.14	22.86	17.14
	M7	67.19	59.38	26.56	15.63	78.13	62.50	53.13	7.81	23.44
	M8	100.00	48.84	32.56	32.56	65.12	67.44	66.32	48.84	65.12
	M9	33.33	29.63	11.11	18.52	37.04	22.22	37.04	22.22	18.52
	Total	63.56	46.55	21.83	32.42	57.30	54.57	43.18	27.45	26.81
		χ^2=76.51 p=0.000*	χ^2=23.30 p=0.003*	χ^2=40.86 p=0.000*	χ^2=78.50 p=0.000*	χ^2=33.85 p=0.000*	χ^2=47.52 p=0.000*	χ^2=46.15 p=0.000*	χ^2=42.22 p=0.000*	χ^2=67.47 p=0.000*
Impediment to carry out daily activities over the last year	M1	24.09	16.79	5.84	12.41	31.39	36.50	21.17	11.68	10.95
	M2	24.72	15.73	15.73	33.71	19.10	24.72	33.71	15.73	8.99
	M3	26.92	19.23	0.00	15.38	19.23	15.38	19.23	11.54	11.54
	M4	37.84	21.62	10.81	27.03	40.54	37.84	21.62	10.81	16.22
	M5	48.53	11.76	36.76	63.24	50.00	63.24	50.00	63.24	25.00
	M6	19.05	12.38	0.00	17.14	30.48	26.67	16.19	13.33	7.62
	M7	31.25	25.00	25.00	25.00	51.56	43.75	40.63	10.94	7.81
	M8	32.56	48.84	0.00	16.28	48.84	65.24	64.15	16.28	65.12
	M9	33.33	29.63	14.81	14.81	25.93	29.63	18.52	11.11	7.41
	Total	29.05	19.90	12.04	24.56	34.35	37.56	30.18	18.30	15.09
		χ^2=22.39 p=0.004*	χ^2=35.26 p=0.000*	χ^2=79.79 p=0.000*	χ^2=78.62 p=0.000*	χ^2=35.17 p=0.000*	χ^2=55.07 p=0.000*	χ^2=66.14 p=0.000*	χ^2=104.47 p=0.000*	χ^2=103.6 p=0.000*

Note: Prevalence is represented in percentages. The asterisk represents significant differences at a 95% confidence level between the MDS prevalence for each furniture model.

diminishes their furniture design proposal validity, given the outstanding anthropometric differences between the German and the Ecuadorian population.

The Ecuadorian technical standard NTE INEN 2583: 2011 [46] establishes the requirements for tables and chairs for students between the second year of primary education until the third year of upper secondary school, as well as the quality tests to which they must fulfill so as to prove their suitability for use. These standard does not include specific measures for the furniture of Higher Education students. In this context, the dimensions of the design parameters for tables, chairs and side-mounted desktop chairs proposed in this study, could be the starting point for the creation of a specific standard that regulates the design of school furniture for university students.

In general, every analyzed study station composed of tables and chairs in the 5 examined universities presented high discrepancy in seat height and seat depth, and also in desk height and under-desk height. Likewise, all of them presented a low mismatch in the table width and the table depth. On the other hand, every chair with side-mounted desktop analyzed showed a high mismatch in the inner and upper tablet height, as well as in seat height. The length and width of the tablet also presented a low mismatch.

This study also demonstrated a dependence between the presence of MDS in university students and the type of school furniture used during the last twelve months. Although the nine analyzed models have at least five mismatches in their design parameters, there is insufficient evidence to affirm that these incompatibilities are the only cause of MDS. Therefore, providing students with furniture that is fully compatible with their anthropometric characteristics will not necessarily guarantee the total absence of MDS.

It is recommended that future researches deepen the identification of such causes, as the prevalence levels identified in this research are quite high considering that 88.76% of the students felt MDS in at least one part of their body during the last year (95% CI: 0.863-0.912). It is also important to note that among the latter, 62.92% (95% CI: 0.591-0.667) reported having been prevented from performing other usual daily activities.

The results show that women who use the furniture models assessed are more likely than men to feel MDS associated with neck, shoulders, upper back, lower back and hips/thighs. Individuals with a BMI greater than 25kg/m2 (considered by the World Health Organization as being overweight/obese [47]) are at increased risk of having MDS along the entire spine and hips/thighs. Sitting longer than 20 hours a week poses a risk for the presence of MDS in the neck, lower back, and knees.

Upper-level students (third, fourth, and fifth year of study) are at increased risk of having MDS in the neck, lower back and hips/thighs. Students who use a side-mounted desktop chair on a day-to-day basis may be more likely to develop MDS in the neck, wrists/hands, and ankles/feet than students using a table and chair. The latter, are more likely to have problems in the lower back. The results also demonstrate that being left-handed and over 25 years of age are not risk factors for the presence of MDS in

Table 7: Risk factors related to annual MDS prevalence in university students

Caracteristics	Neck	Shoulders	Wrists/ Hands	High back	Low back	Hips/ Thighs	Knees	Ankles/ Feet
Female gender	2.431[a] (1.73-3.42)	2.837[a] (2.05-3.93)	1.214 (0.86-1.69)	1.737[a] (1.25-2.40)	1.759[a] (1.27-2.42)	1.649[a] (1.19-2.27)	0.816 (0.57-1.16)	1.283 (0.90-1.83)
Left-handed	0.516 (0.30-0.85)	0.450 (0.26-0.78)	0.291 (0.14-0.60)	0.216 (0.12-0.38)	0.524 (0.31-0.87)	0.375 (0.20-0.67)	0.326 (0.15-0.69)	0.628 (0.33-1.18)
Over 25 years old	1.062 (0.52-2.12)	0.974 (0.50-1.89)	0.557 (0.25-1.24)	1.239 (0.62-2.45)	0.692 (0.35-1.34)	0.891 (0.45-1.75)	0.977 (0.46-2.06)	1.166 (0.56-2.41)
BMI higher than 25 Kg/m^2	0.694 (0.49-0.98)	0.758 (0.54-1.06)	0.758 (0.53-1.09)	3.151[a] (2.00-4.95)	4.331[a] (2.23-8.40)	2.581[a] (1.83-3.63)	0.906 (0.62-1.32)	0.884 (0.61-1.29)
To be seated more than 20 hours a week	1.968[a] (1.17-3.29)	0.721 (0.52-0.98)	1.064 (0.76-1.48)	0.575 (0.41-0.79)	2.387[a] (1.60-3.55)	0.839 (0.61-1.15)	1.590[a] (1.11-2.27)	0.843 (0.59-1.20)
More than 2 years studying	1.766[a] (1.02-3.03)	0.949 (0.67-1.34)	1.449 (0.99-2.13)	1.195 (0.84-1.69)	1.492[a] (1.05-2.11)	1.648[a] (1.15-2.36)	2.850 (1.80-4.52)	1.278 (0.85-1.91)
Use of side-mounted desktop chair	1.585[a] (1.14-2.20)	1.227 (0.89-1.69)	1.674[a] (1.18-2.37)	1.015 (0.74-1.40)	0.713 (0.52-0.98)	1.369 (0.99-1.89)	1.243 (0.87-1.78)	2.065[a] (1.42-3.01)
Use of table/chair	0.631 (0.45-0.88)	0.815 (0.59-1.12)	0.597 (0.42-0.85	0.985 (0.72-1.36)	1.402[a] (1.02-1.93)	0.730 (0.53-1.01)	0.804 (0.56-1.15)	0.484 (0.33-0.71)

Note: Values correspond to OR. Ranges in parentheses stand for 95% OR confidence intervals. Superscript represents the OR is significant at a 95% confidence level.

university students.

In considering the presence of MDS in the nine parts of the body as nominal variables, the statistical techniques that could be applied were limited. In this regard, in addition to the presence of MDS it is recommended to study the intensity of pain perceived by students, this would increase the spectrum of statistical tools that could be used to delve into the problem.

The imminent solution to avoid the high prevalence of MDS in the students of the analyzed universities would be to change all school furniture in the short term, however, such corrective measure is impractical due to the high amount of the initial investment. A more economical alternative would be to adopt the policy of taking five minutes of active pauses between each hour of work in the classroom so that students can stretch their limbs and reduce exposure to bad postures that can produce pain, swelling, paresthesia, or any other musculoskeletal disorder symptom.

The human body is not designed to remain seated for long periods of time. Intervertebral discs do not have an independent blood supply and depend on the pressure changes that result from the body movement to receive nutrients and to discard their metabolic wastes [41]. The rigidity of the posture also reduces blood flow to the muscles and induces muscle fatigue and cramps [41].

In the same way, it would be advisable for higher education institutions to carry out campaigns to promote awareness in students about the importance to adopt the right postures when performing academic activities in a seated position.

5. Conclusions

This research determined ten design parameters for classroom furniture design for Ecuadorian university students based on relevant anthropometric information. Classroom furniture here examined were composed of tables with its correspondent chairs, and also side-mounted desktop chairs. These results are particularly relevant as they could stand as a starting point to the creation of a specific Ecuadorian standard to regulate classroom furniture design for university students. That would ensure domestic and foreign manufacturers could offer furniture more secure and adequate to the anthropometric characteristics of the university population of Ecuador.

Taking the above-mentioned measures as a reference, a sample of 9 school furniture models that were used in 5 universities of the city of Guayaquil was evaluated based on the computed match intervals and it was found that 100% does not fit, in at least five design parameters, to the anthropometric characteristics of its target population. Only the width of the chair backrest was within the matching range.

A high prevalence of musculoskeletal disorders symptoms (MDS) was found in students over the last year, mainly in the neck, along the whole spine and in the hips or thighs. Also, the percentage of students who reported having perceived these symptoms and thereby prevented other usual non-academic activities were significantly different for each model of furniture. This demonstrated that there is a relationship of dependence between the type of furniture and the presence of MDS in some parts of the body.

This study also showed evidence that female students who spend more than 20 hours per week sitting at a side-mounted desktop chair are at greater risk of having MDS in the neck than men. Also, women who are overweight or obese (BMI over 25 kg/m^2) are at higher risk of having MDS in the upper back and hips or thighs, and those that have studied more than two years in higher education institutions and spend more than 20 weekly hours using desk and chair study stations have a greater risk of having MDS in the lower back.

All of the above-mentioned findings support the need to extend the research immediately to a national level to identify the real prevalence of MDS in the Ecuadorian university students, provide the required medical rehabilitation if necessary, and establish a strategy that allows the gradual acquisition of safer and appropriate classroom furniture that matches students' anthropometric characteristics.

Conflict of Interest

The author declares no conflict of interest with any individual or organization.

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