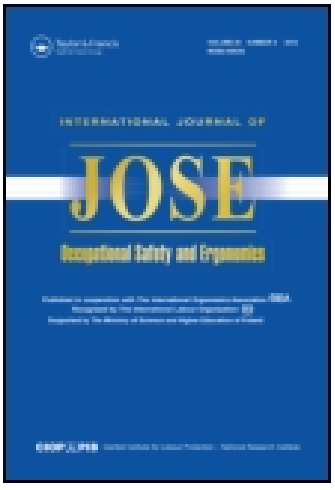

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A Carpet-Weaver's Chair Based on Anthropometric Data

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A Carpet-Weaver's Chair Based on Anthropometric Data

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Ergonomic design of chairs has been well studied by ergonomists. Chair design based on anthropometric data analysis is recommended. Weavers in carpet-weaving workshops use chairs with backrests and armrests. An anthropometric survey was carried out among weavers in Tabriz, Iran, to design a flexible chair and to improve its comfort on the basis of design dimensions. This study focused on the design dimensions of a chair for weavers and its recommended dimensions. The developed chair needs to be tested for its effects on weavers' posture and comfort.

anthropometric data weaver's chair ergonomic design comfort

1. INTRODUCTION

Every day, people spend much time in seated posture, while eating, driving, meeting, watching television, etc. Almost 75% of workers in industrial countries (70% in the USA) do their jobs in seated posture [1]. Like many other tasks, weaving carpets by hand is sedentary work, with 91.7% of weavers working on a vertical loom and sitting on the ground or on a piece of lumber [2]. Andersson, Ortengren, Nachemson, et al. found that sitting required less muscular work than standing [3] but, according to Choobineh, improper chair design affects weavers' functions and causes backache [2].

Seating comfort is strongly connected with the postural support features of the seat. It is desirable to design seats that can provide comfortable and controlled seated posture [4]. Lumbar support can reduce load on the spine [3, 5]. Andersson et al.'s research demonstrated that lumbar support could reduce intradiscal on the lumbar spine [3].

Back support is another postural support feature. Hedge and Ruder found that sitting with a backrest in a free-float mode improved the users' back support as they worked on the computer [6]. Umezawa and Yamaguchi (as cited in Grandjean [7]) showed that leaning back could lead to more neutral postures. They also showed that both the seat and the backrest angle contributed to that effect.

The major purpose of seat designers is to design a seat for most (90%) users with different dimensions [1]. Also, to eliminate the problems of tall, short and overweight users, designers should pursue some particular solutions [8]. Dainoff, Mark, Ye, et al.'s statement that "a chair is not an isolated object, but needs to be considered as an integrated component in a complex work environment" (p. 10) [9] means that a seat is a very important parameter in decreasing many problems such as musculoskeletal disorders (MSDs).

According to Choobineh, Lahmi, Shahnavaz, et al., there is an association between seat type and the occurrence of MSDs with neck, shoulder, upper back, lower back, thigh and knee symptoms [10]. Musculoskeletal problems in those regions occur in higher rates in weavers who sit on the ground or on a piece of lumber ($p < .05$) [10]. An incorrect design of a weaver's seat and, thus, improper posture, are conducive to developing MSDs; however, with an ergonomic seat and instructions, users can avoid MSDs [11, 12].

Hence, this study was conducted to intervene at a workstation for weaving carpets by hand and to design an ergonomic seat (based on weavers'

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anthropometric dimensions) and postural support, which should reduce the prevalence of MSDs in weavers.

2. MATERIALS AND METHODS

This study was conducted in Tabriz, the capital of East Azerbaijan in northwest Iran. It was conducted over 4 months, beginning in July 2010. Ten active carpet-weaving workshops in the area were selected for this study. A random group of 50 weavers was selected from these workshops to participate. A total of 47 males declared their agreement to assist. All participants were familiarized with the study, the investigator answered their questions; they had the opportunity to refuse participation. Each weaver signed a consent form before participating in the study, which the local ethical review committee had approved.

Data were collected with a questionnaire. Arrangements were made with individual workshops and the questionnaires were completed by interviewing the weavers. There were two types of questions: (a) on demographic and job items, workstation design and tools, environmental conditions of the workstation and (b) on the presence of musculoskeletal symptoms in different body regions. The questionnaire first recorded demographic data (age, weight, height, body mass index [BMI], experience and daily work time) and some body dimensions required for designing a seat (Figure 1).

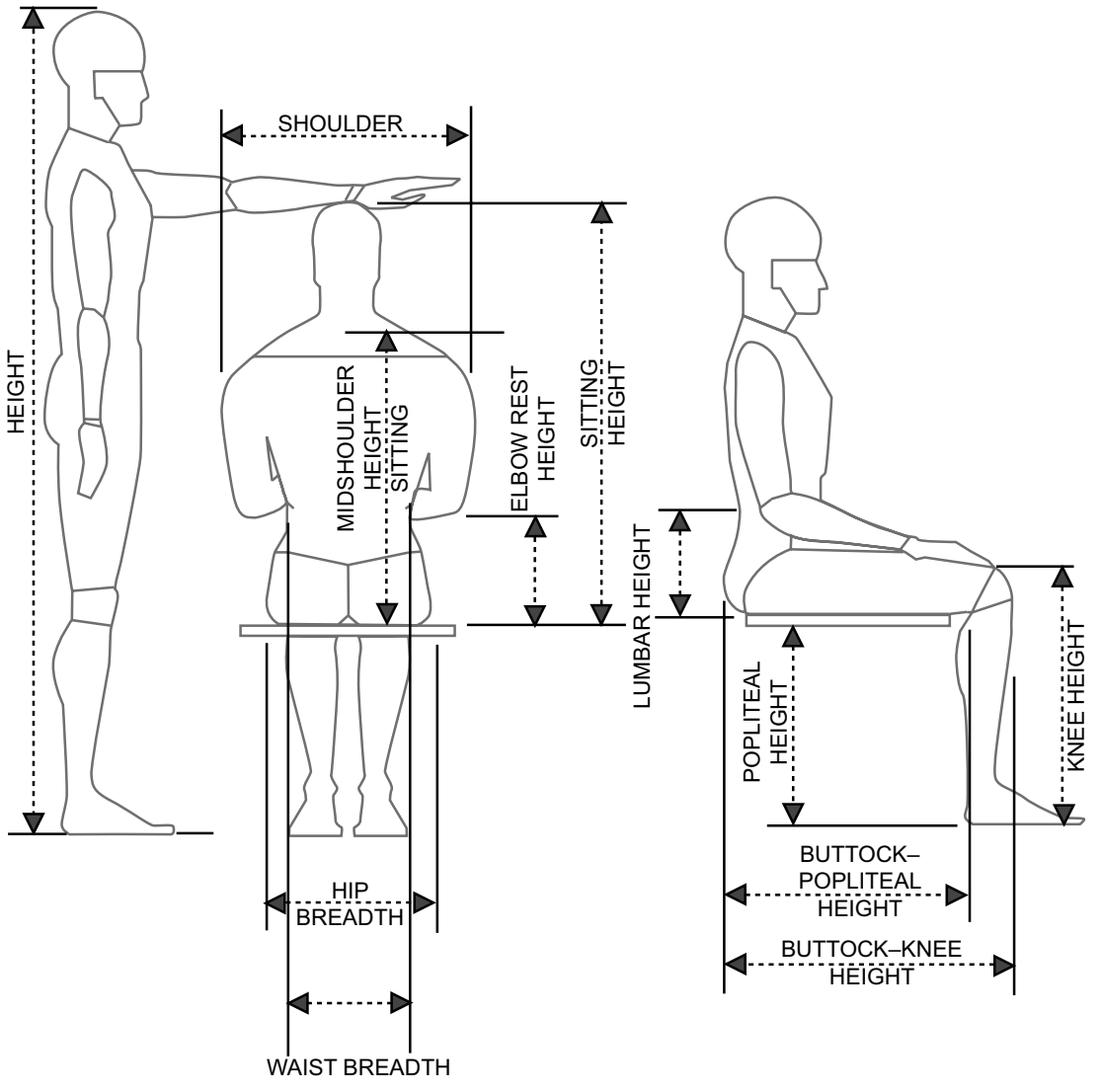

Figure 1. A guideline for measuring anthropometric dimensions.

An adjustable stool was used to measure the weavers' body dimensions with an Iranian anthropometer (Figure 2). It was tested for accuracy in measurements, and was found to be accurate. The measurements were taken according to the procedure described by Pheasant [13] and Abeysekara [14]. During the measurements, the subjects wore normal light clothes with empty pockets, and no shoes. All sitting measurements were taken with the subjects sitting in a fully erect posture, so that the knees and ankles formed right angles.

This study used protocols from Standards No. ANSI-HFES 100-2007 [15] and BSR-HFES 100-2002 [16] to design an ergonomic chair for workstations for weaving carpets by hand. The percentiles (5th, 50th and 95th) were calculated with SPSS version 16 and the proposed chair with all its components was designed with CATiA V5R19[1].

3. RESULTS

In the first part of the study, the participants answered questions on their age, experience, daily work time and work content, and the occurrence of musculoskeletal complaints. Their weight and height were measured; BMI was computed.

Figure 2. An adjustable stool for measuring body dimensions.

Table 1 shows some personal characteristics of the weavers. Their mean age and age range indicate that they were young. They were experienced, as each weaver had a mean experience of almost 13 years. Their daily work time was normal.

TABLE 1. Personal Characteristics of Weavers Who Weave Carpets by Hand

Characteristic	*M* (*SD*)	Range
Age (years)	28.8 (9.2)	18–58
Weight (kg)	68.4 (10.4)	52–98
Height (cm)	175 (6.6)	160–189
BMI	22.4 (3.1)	17.9–29.4
Experience (years)	12.8 (6.2)	3–25
Daily work time (h)	7.9 (1.7)	5–14

Notes. BMI = body mass index.

Table 2 presents the prevalence of MSD symptoms in different regions of the weavers' bodies in the past 12 months. The neck, lower back, and ankles and feet were the most commonly affected regions.

TABLE 2. Prevalence of Symptoms in Different Body Regions in Past 12 Months (*n* = 47)

Body Region	No. (%)
Neck	37 (78.7)
Shoulders	23 (48.9)
Elbows	13 (27.7)
Hands and wrists	26 (55.3)
Upper back	25 (53.2)
Lower back	32 (68.1)
Thighs	8 (17.0)
Knees	23 (48.9)
Ankles and feet	30 (63.8)

In the second part of the study, anthropometric dimensions necessary for designing a carpet-weaver's chair were measured with an anthropometer (Table 3).

Table 4 presents criteria for designing a seat according to body dimension percentiles computed from the weavers' anthropometric dimensions in Table 3. The calculated average shoe

[1] http://www.3ds.com/products-services/catia/

TABLE 3. Weavers' Dimensions Necessary in Designing a Seat (n = 47)

	Percentile			
Dimension (cm)	5th	50th	95th	*M* (*SD*)
Height	163.2	175	187.8	174.7 (6.6)
Shoulder height	58.0	62	69.2	62.7 (3.6)
Knee height	48.5	54	60.6	54.1 (3.6)
Popliteal height	40.0	43	49.6	43.8 (3.1)
Buttock–knee	52.0	57	64.6	57.1 (3.7)
Popliteal depth	42.0	47	54.6	43.8 (3.1)
Lumbar height	20.0	26	28.6	25.5 (2.4)
Shoulder length	36.4	44	50.0	43.4 (3.9)
Waist length	24.0	31	38.6	30.9 (5.0)
Waist depth	17.0	22	34.8	23.5 (4.9)
Buttock length	29.4	37	43.0	37.0 (4.2)
Armrest height	21.0	25	29.2	25.0 (2.5)

TABLE 4. Some Seat Characteristics Computed From Weavers' Anthropometric Dimensions

Parameter	Value (cm)	Design Criterion
Seat height	42.5	(P_{5th} of popliteal height + 2.5 cm shoe allowance)
Seat pan depth	42.0	P_{5th} of buttock–popliteal length
Seat pan width	43.0	P_{95th} of buttock length
Armrest height	21.0–29.2	P_{5th} armrest height–P_{95th} armrest height
Lumbar support height	20.0–28.6	P_{5th} lumbar height–P_{95th} lumbar height
Backrest height[a]	58.0	P_{5th} shoulder height
Backrest width	38.6	P_{95th} waist length

Notes. a = measured when weavers were sitting; P_{5th}, P_{95th} = 5th and 95th percentile, respectively.

TABLE 5. Standards No. ANSI/HFES 100-2007 [15] and BSR/HFES 100-2002 [16] and Their Requirements and Recommendations for Ergonomic Chair Design

	ANSI/HFES 100-2007		BSR/HFES 100-2002	
Parameter	Requirement	Recommendation	Requirement	Recommendations
Seat height (adjustable)	38–56 cm		38–56 cm	
Seat pan tilt (backward)	4°–6°		≤6°	
Seat pan–backrest angle	90°–105° or 90°–120°		≥90°	
Seat pan–backrest recline[a]	0°–15°		0°–15°	
Seat pan depth	≤43 cm			≤43 cm
Seat pan width	≤45 cm			≥45 cm
Backrest width		≥36 cm		≥36 cm
Backrest height		≥45 cm above CSH		≥45 cm above CSH
Lumbar support (adjustable)		15–25 cm above CSH		15–25 cm above CSH
Armrest height (fixed)		17–27 cm		17–27 cm
Armrest height (adjustable)		18–27 cm		18–27 cm
Armrest span		46 cm		

Notes. a = recommended range in both standards: 0°–30° (>30° if head rest necessary); CSH = compressed seat height.

allowance considered in seat height in Iranian carpet weavers is 2.5 cm [1].

Table 5 compares the requirements and recommendations in two standards for an ergonomic chair, Standards No. ANSI-HFES 100-2007 [15] and BSR-HFES 100-2002 [16].

Finally, Table 6 results from Tables 4–5; it shows specifications of an ergonomic chair for weavers in Tabriz. Figure 3 illustrates the dimensions of the new carpet-weaver's chair. However, the weaving loom should be changed to a rotative one, like the one in Figure 4 (from the Carpet Department of the Islamic Art University of Tabriz), which does not require elevating seat height after working for a time.

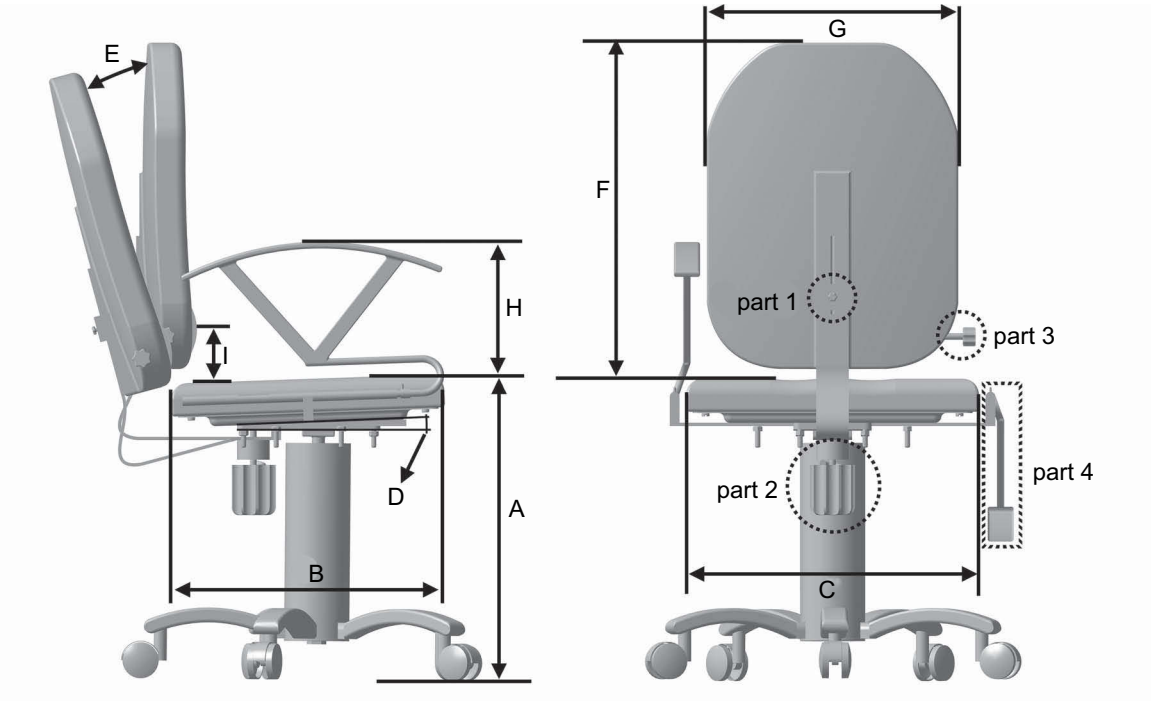

Figure 3. Dimensions of the new carpet-weaver's chair. *Notes.* A, B, C, D, E, F, G, H, I = see Table 6.

TABLE 6. Dimensions of the New Carpet-Weaver's Chair

Parameter		Value
Seat height (adjustable)	A	38–56 cm
Seat pan depth	B	43 cm
Seat pan width	C	45 cm
Seat pan tilt (backward)	D	5°
Seat pan–backrest angle (adjustable)	E + 90°	90°–105°
Backrest height	F	50 cm
Backrest width	G	38.6 cm
Armrest height (adjustable)	H	18–27 cm
Lumbar support height (adjustable)	I	15–30 cm

Notes. A, B, C, D, E, F, G, H, I = see Figure 3.

Figure 4. A rotative weaving loom built at the Carpet Department of the Islamic Art University of Tabriz, Iran.

4. DISCUSSION

The proposed carpet-weaver's chair designed on the basis of anthropometric dimensions should increase the weavers' comfort at work. As carpet weaving is a traditional handicraft industry, humans play a crucial role. The basic tool they need is a well-designed chair that increases their comfort during weaving.

Table 2 shows that MSDs are common among carpet weavers. Over half of weavers experience MSDs in different body regions. Choobineh et al. demonstrated with logistic regression analysis that seat type was a significant factor in the involvement of the shoulders, neck, upper back, lower back and thighs in MSDs [10]. So, the present study was conducted to design a seat with all supports and principles for designing a weaver's seat based on male weavers' anthropometric dimensions. Sections 4.1.–4.9. discuss literature relevant in the process of designing ergonomic chairs.

4.1. Seat Height

Mehta, Gite, Pharade, et al. stated that seat height should be low enough to avoid excessive pressure on the thigh [17]. They measured this parameter with the 5th percentile of popliteal height. Based on the anthropometric results of that study, the seat height should be 42.5 cm including the allowance for shoes; however, in Standard No. ANSI/HFES 100-2007, this parameter is adjustable between 38 and 56 cm [15]. Due to this range, the preferred seat height is 38–56 cm. A screw is used for adjusting seat height. Seat pan height is adjusted by rotating the chair around the axis of the screw.

4.2. Seat Pan Depth

Seat depth, calculated with the 5th percentile of buttock–popliteal length, should be 42 cm, which is confirmed by Standards No. ANSI-HFES 100-2007 [15] and BSR-HFES 100-2002 [16], Pheasant [13] and Grandjean [18]. Those standards and studies require seat depth to be at most 43 cm.

4.3. Seat Pan Width

According to Standard No. ANSI-HFES 100-2007, seat width should be determined with the 95th percentile of women's buttock length [15]. Since this study did not measure women, we used the 95th percentile of men's buttock length. This dimension was calculated to be 43 cm, but the standards require at least 45 cm.

4.4. Armrest Height

Armrest height in Standard No. ANSI-HFES 100-2007 is 18–27 cm [15]; it should be adjustable. According to Table 4, it is 21.0–29.2 cm. So, in this study, the standard for this part of seat is accepted because the deviation from this standard is only 0.2 cm. During weaving, a weaver's elbow and arm should be dynamic in the working area, with no limitations. That is why it should be possible to remove armrests in a carpet-weaver's chair. Armrests in the proposed design can be moved from their position to a position beside and lower than the seat pan (Figure 3, part 4).

4.5. Backrest Width

According to Table 4, backrest width should be 38.6 cm, which confirms the recommendation of Standard No. ANSI-HFES 100-2007 for this component of an ergonomic seat [15]. However, for aesthetic reasons [1], backrest width should equal seat pan width.

4.6. Backrest Height

Because of shoulder and arm movements, a short backrest is preferable in an ergonomic seat. This kind of backrest protects the lumbar spine [13]. Due to the constant movement of shoulders during weaving, this part of the chair is shorter. The 5th percentile of shoulder height of Iranian weavers is ~60 cm (58 cm). Thus, after subtracting 10 cm from shoulder height to allow for free shoulder movement, backrest height should be 50 cm. Moreover, the designed backrest height is adjustable with a screw behind the backrest (Figure 3, part 1). In this way, the height of the backrest can be adjusted to increase the users' comfort.

4.7. Seat Pan Tilt

Standard No. ANSI-HFES 100-2007 suggests the correct seat pan tilt [15], which prevents the operator from slipping on the seat pan and helps in full back support. In the standards, this parameter is 4°–6°. In this study, ~5° to backward.

4.8. Seat Pan–Backrest Angle

Backrest inclination, which helps the operator lean and be comfortable, is a significant part of the seat. This angle should be over 90°. Standard No. BSR-HFES 100-2002 [16] requires the angle to be ≥90°, whereas Standard No. ANSI/HFES 100-2007 [15] requires 90°–105°. Morever, it indicates that if this angle is 90°–120°, a headrest is necessary. So, the best angle is 90°–105°. Thus, there is a screw for adjusting the inclination of the backrest. The screw is under the seat pan (Figure 3, part 2); it changes the backrest angle.

4.9. Seat Lumbar Support

Lumbar support is in the lower part of the seat backrest; it helps lordosis. That is why it is an important part of an ergonomic chair, and adjustable lumbar support is necessary. Anthropometric measurements show that lumbar support should be adjustable between 20.0 and 28.6 cm, but Standards No. ANSI-HFES 100-2007 [15] and BSR-HFES 100-2002 [16] recommend 15–25 cm above compressed seat height. So, this characteristic in the new seat is 15–30 cm to meet all users' expectations and to comply with the standards. The screw beside the seat backrest helps the operators to adjust lumbar support (Figure 3, part 3).

The proposed chair based on anthropometric data should decrease inconvenience. In this study, data were analysed with appropriate accuracy to help design a carpet-weaver's chair. Dimensions were ignored when they were not in line with the standards. While helping comfortable postures, carpet-weaver's chairs should also support weavers' activities. To that end, new features based on weavers' expectations were developed and new dimensions proposed. Table 6 lists the characteristics of an ergonomic weaver's chair. Armrest height was calculated so as not to disturb weaving; armrests are removable. Because of aesthetics, backrest width should equal seat pan width. In determining backrest height, because the shoulders and arms move during weaving, 10 cm were subtracted from the 5th percentile of weavers' shoulder height. Seat pan tilt prevents weavers from slipping. Seat pan–backrest angle makes it possible for operators to lean; it increases the level of comfort. Adjustable lumbar support helps lordosis.

5. CONCLUSION

This study showed that MSDs were common among weavers. An ergonomic seat with adjustments for carpet weavers could help reduce MSDs and improve their comfort. This would, in turn, help raise productivity and safety in weaving.

This study showed that the required effective parameters in designing seat height, seat depth, seat width, armrest height, lumbar support, backrest height and backrest width of a weaving seat were, respectively, popliteal height (5th percentile), popliteal depth (5th percentile), buttock length (95th percentile), armrest height (5th and 95th percentiles), lumbar height (5th and 95th percentiles), shoulder height (5th percentile) and waist length (95th percentile). Moreover, Standards No. ANSI-HFES 100-2007 [15] and BSR-HFES 100-2002 [16] are helpful in designing seats unless they are not in step with anthropometric dimensions.

The purpose of this study was to provide confidence and comfort for weavers. Further studies are necessary to design and develop a new seat and to test it on weavers.

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