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Workstation Design in Carpet Hand-Weaving Operation: Guidelines for Prevention of Musculoskeletal Disorders

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Carpet weavers suffer from musculoskeletal problems mainly attributed to poor working postures. Their posture is mostly constrained by the design of workstations. This study was conducted to investigate the effects of 2 design parameters (weaving height and seat type) on postural variables and subjective experience, and to develop guidelines for workstation adjustments. At an experimental workstation, 30 professional weavers worked in 9 different conditions. Working posture and weavers' perceptions were measured. It was shown that head, neck and shoulder postures were influenced by weaving height. Both design parameters influenced trunk and elbows postures. The determinant factor for weavers' perception on the neck, shoulders and elbows was found to be weaving height, and on the back and knees it was seat type. Based on the results, the following guidelines were developed: (a) weaving height should be adjusted to 20 cm above elbow height; (b) a 10º forward-sloping high seat is to be used at weaving workstations.

weaving workstation design   carpet hand-weaving operation   musculoskeletal problems, working posture

1. INTRODUCTION

It has been widely accepted that awkward and constrained postures result in musculoskeletal stress on different body regions of seated workers [1] and are a major factor in the development of musculoskeletal disorders [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12]. Poor postures have also been found to be associated with decreased efficiency of performance, which is mainly caused by body discomfort resulting from restricted postures [13, 14]. The need to improve working posture has been documented in a number of studies which have shown a relation between stressful postures

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at work and functional disturbance or pain in various parts of the musculoskeletal system [5]. The effect of poor postures will continue unless proactive steps are taken to evaluate and reduce the problem. More suitable working postures may have a positive effect on workers' musculoskeletal systems, and may allow for more effective control of work performance and reduction in the number of occupational injuries [15].

The postural problems appear to be largely caused by improperly designed and ill arranged workstation furniture [16, 17]. Postures are often prescribed by the design of the work situation. By studying the posture of a worker during his/her daily work, one studies the design of the work place at the same time [2]. There can be no more fundamental aspect of occupational ergonomics than the concern with the design of the workstation at which workers must spend considerable time and effort doing their jobs [18]. The aim of workstation design is to minimize the users' harmful postures and design-imposed stresses [10]. There is general agreement that in any work setting a well-designed workstation furthers not only the health and well-being of the workers, but also productivity and the quality of the products. Conversely, a poorly designed workstation is likely to cause or contribute to the development of health complaints or chronic occupational diseases, as well as to problems with keeping product quality at a prescribed level [18, 19, 20]. Users of ergonomically designed workstations are likely to benefit in terms of task performance, as well as in terms of less discomfort/fatigue, sick leave, and disability caused by musculoskeletal load [21].

Carpet weaving is one of the most tedious professions, requiring long hours of static work [22] and it is a high-risk occupation for developing musculoskeletal disorders as awkward posture, repetitive movements, contact stress and long working time are common [23]. The weaving operation is characterized by a sitting posture with the weaver's head and trunk flexed forward (Figure 1). The task involves simultaneous but different motions with the two hands. The weaver begins the carpet from the bottom and works upwards. As the weaving progresses, the carpet is shifted behind the loom. Upon completion of a row of knots, the weaver passes the horizontal thread, called weft, through the vertical thread, called warp, across the width of the carpet and firmly presses on the knots with a weaving comb. The ends of the knots, which have been cut roughly with a knife at the time of each knotting are then trimmed with a special pair of scissors to make them even with the face of the carpet. This work activity is maintained throughout the whole work shift.

Figure 1. A weaving operation performed in a seated posture with a forward inclination of the head and trunk and shoulder flexion.

As a result of the poor working posture of the neck, trunk, upper extremities and knees, repetitive movements and long working time, there is a high prevalence of musculoskeletal complaints affecting the neck, back, upper limbs and knees among weavers [24, 25]. In a survey of 1,439 weavers in the Iranian hand-woven carpet industry, Choobineh et al. [25] found that substantial numbers of weavers suffered musculoskeletal symptoms such that 81.17% of the study population experienced some kind of symptoms during the past 12 months. The most commonly affected regions among the weavers were shoulders (47.8%), the lower back (45.2%), the wrists (38.2%), the upper back (37.7%), the neck (35.2%) and the knees (34.6%). In a study on 50 weaving workshops, it was found that working posture and workstation design were the major ergonomic problems in the workshops [23]. Choobineh et al. [25] believed that the majority of ergonomic shortcomings and important factors for the development of musculoskeletal disorders in a weaving operation originated from ill-designed workstations. They pointed out that any working conditions improvement program in a weaving operation had to focus on designing an ergonomic-oriented weaving workstation. They developed some general, qualitative guidelines for weaving workstation design in which adjustability was in the centre of attention and with a prototype test showed that the new workstation improved the working posture. They concluded that although working posture had been considerably improved, quantitative guidelines for optimizing working posture were still needed.

As a continuation of previous work, the present study was conducted to investigate the effects of two workstation design parameters (weaving height and seat type) on postural variables and the subjective experience of the weavers, as well as to develop quantitative guidelines for adjusting a weaving workstation in order to improve working posture and minimize the load on musculoskeletal system during operation.

2. MATERIALS AND METHODS

The loom and the prototype weaving workstation designed and constructed in the previous study [25] was used in this experiment. In the laboratory, nine sets of experimental conditions were tested. Measurements were made of weavers' working postures and their subjective experience while they worked at the designed workstation under the nine sets of experimental conditions of the main design parameters of "weaving height" and "seat type" [26].

2.1. Subjects

A total of 15 male and 15 female subjects participated in this study; their details are shown in Table 1. All subjects were professional weavers and all had normal conditions of health and eyesight. The subjects were paid an industrial hourly rate for the time spent on the experiment.

TABLE 1. Details of the Subjects

Subjects	*M*	*SD*	Range
Age (years)	29.5	7.6	18–43
Weight (kg)	64.9	9.6	45–80
Stature (cm)	166.3	8.5	153–180
Experience in weaving (years)	12.5	9	3–35

2.2. Experimental Procedure

In a factorial design of 3 × 3, at the adjustable experimental workstation, the weavers performed their normal weaving task in nine experimental sessions of 45 min followed by breaks of 15 min. In each session, one of the nine sets of experimental conditions was presented. The sets of experimental conditions were presented in random order to counterbalance the carry-over and order effects. The duration of an experimental session was chosen in accordance with the average time that a professional weaver needed to complete a work cycle. The first day consisted of six sessions and the following day of three sessions. Prior to the test session, each subject selected a preferred distance between the seat and the loom. This distance was then kept the same for each experimental condition tested.

2.3. Independent Variables

The nine sets of experimental conditions consisted of different combinations of "weaving height" and "seat type". The weaving heights (height of the location of knotting) tested, covering the range of weaving height adjusted in the industry, were related to the individual elbow height of the weaver:

- 10 cm above elbow height (+10 cm),
- 20 cm above elbow height (+20 cm),
- 30 cm above elbow height (+30 cm),

where elbow height was defined as the distance from the floor to the underside of the elbow with the weaver sitting upright, the upper arms hanging down, and the forearms horizontal.

The seat types tested were as follows:

- Conventional seat: a flat seat with the height equal to the weaver's popliteal height,
- High seat: a 10º forward-sloping seat with the height equal to the weaver's popliteal height plus 15 cm,
- Traditional seat (bench): a flat seat currently used in most weaving workshops. The weaver sat on the bench in a cross-legged posture.

To prevent the interference of the effect of a backrest on the experiment results, none of the seats was equipped with a backrest.

2.4. Dependent Variables

Working posture was measured by WEPAS, a two-dimensional video-based system for recording and analyzing weaving posture developed on the basis of image processing technology [27]. As the working posture under examination in this study was largely two-dimensional, in the sagittal plane, it was, therefore, felt that the objectives of the study could be met with a 2D analysis. Reflective markers were placed at the eye (outer canthus), the ear (tragus), the neck (C7), the hip (greater trochanter), the shoulder (greater tubercle), the elbow (lateral humeral epicondyle), and the wrist (styloid process of ulna) (Figure 2). The markers were put on the right side of the body, due to the dominant role of the right hand in a weaving operation. The marker positions were determined during a weaving operation at each of the experimental conditions, as well as while the weavers were in a neutral posture (sitting upright, symmetric with respect to the sagittal plane, looking straight ahead along the horizontal, arms hanging down along the trunk, forearms perpendicular to the upper arms). On the basis of the marker positions, the following dependant variables were calculated (Figure 2):

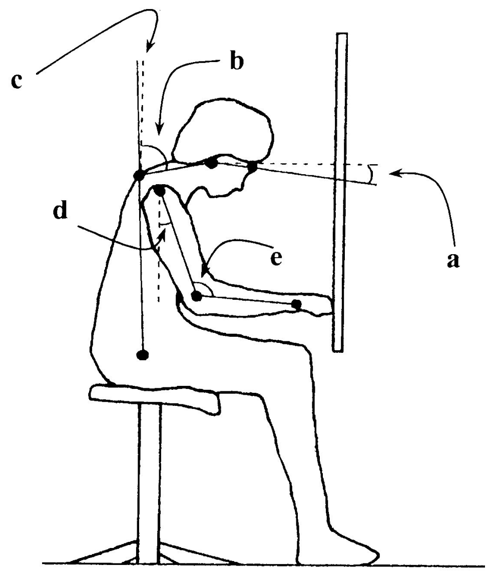

Figure 2. Marker positions and postural angles measured. The dotted lines are horizontal and vertical reference lines. *Notes*. a—head inclination (HI), b—neck inclination (NI), c—trunk inclination (TI), d—arm angle (AA), e—elbow angle (EA).

- **Head inclination (HI),** defined as the angle between the horizontal and the line through the markers at the eye and the ear. A negative value means the head is inclined forwards.
- **Neck inclination (NI),** defined as the angle between the vertical and the line through the markers at the ear and the neck. A negative value means the neck is inclined backwards.
- **Trunk inclination (TI),** defined as the angle between the vertical and the line through the markers at the neck and the hip. A negative value means the trunk is inclined backwards.
- **Arm angle (AA),** defined as the angle between the vertical and the line through the

markers at the shoulder and the elbow. A negative value shows arm extension.

- **Elbow angle (EA),** defined as the angle between the line through the markers at the shoulder and the elbow and the line through the markers at the elbow and the wrist.

In each experimental condition, the subject performed the weaving task for approximately 15 min to become accustomed to the arrangement. The subject's posture was then recorded for 10 min. Then, she/he continued working for a further 20 min to complete the session of 45 min. For postural analysis, averages of the postural variables over the 10 min of recording were used. To compare the nine sets of experimental conditions, deviation of postural angles from the neutral posture was used.

Weavers' perceptions were recorded with a questionnaire containing three modules (rating techniques).

1. Perceived posture
   The weaver was asked to rate her/his perception of the posture of the neck, back, shoulders, elbows, and knees. Directly after the session, a written response was given on a 7-point scale (1—*very favourable*, 3—*favourable*, 5—*unfavourable*, 7—*very unfavourable*. For intermediate responses the scores of 2, 4 and 6 were available).

2. Localized postural discomfort
   The weaver was asked to rate her/his postural discomfort in five regions including the neck, back, shoulders, elbows, and knees shown on a diagram of the rear view of a human body, using a visual numeric rating scale [28, 29] ranging from 0 (*no discomfort*) to 9 (*very severe discomfort*). A written response was given at the end of each session. An overall dependent variable was also constructed, i.e., postural discomfort of the whole body [21] by summing the resulting scores for all five body regions divided by 5. It is believed that this variable provides reliable results for comparison of conditions, such as in the present study [21].

3. Judgement on workstation adjustment
   Firstly, the weaver was asked to judge the weaving height. Directly after the session, a written response was given on a 5-point scale (1—*too low*, 2—*a little low*, 3—*right*, 4—*a little high*, and 5—*too high*). Secondly, the weaver was asked to judge the seat type on a 4-point scale. Directly after the session, a written response was given on a 4-point scale (1—*very appropriate*, 2—*appropriate*, 3—*inappropriate*, 4—*very inappropriate*). Finally, the weaver was asked to judge the whole workstation adjustment as compared to her/his own workstation adjustment in industry. Directly after the session, a written response was given on a 5-point scale (1—*much better*, 2—*a little better*, 3—*equal*, 4—*a little worse*, 5—*much worse*).

2.5. Data Analysis

The effects of weaving height and seat type on postural variables, as well as on the variables relating to localized postural discomfort were tested with Analysis of Variance (ANOVA) for Repeated Measures. Differences between sets of experimental conditions were tested using the paired *T* test and the Bonnferroni's Multiple Comparisons Test. The effects of weaving height and seat type on perceived posture and judgement on workstation adjustment were tested with the Friedman test. Differences between sets of experimental conditions were tested with the Wilcoxon test. The selected level of significance in all tests was $\alpha = .05$, and where necessary, Bonnferroni's criteria for Multiple Comparisons.

3. RESULTS

3.1. Postural Variables

The results of the measurement of postural angles in the nine experimental conditions are presented in Figure 3. The values given in Figure 3 show the average amount of deviation of each postural angle from the neutral posture in the test subjects. Regarding this, in each case, the closer a value to zero, the more appropriate the posture adopted by the subject.

3.1.1. Head inclination

Analysis of variance showed that weaving height had a highly significant effect on head inclination ($F = 108.14$; $p < .0001$). Weaving height +30 cm causes a more upright head posture than weaving heights +20 cm and +10 cm (Figure 3a). Seat type showed no significant effect on head inclination.

3.1.2. Neck inclination

Analysis of variance showed that weaving height had a highly significant effect on neck inclination

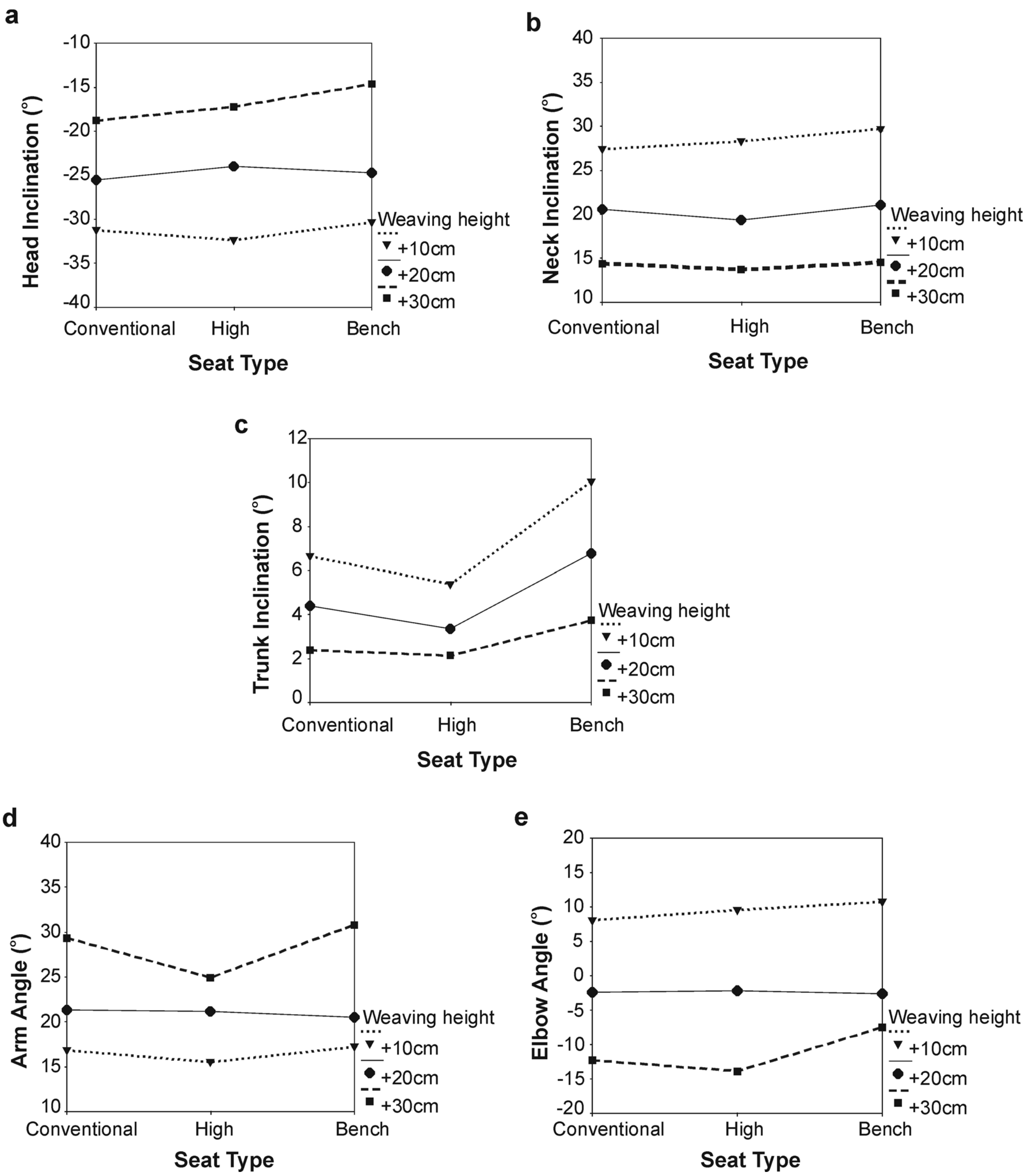

Figure 3. Postural variables in different experimental conditions (average group values): (a) head inclination, (b) neck inclination, (c) trunk inclination, (d) arm angle, (e) elbow angle.

($F = 116.46$; $p < .0001$). Weaving height +30 cm leads to a more upright neck posture than weaving heights +20 cm and +10 cm (Figure 3b). Seat type showed no significant effect on neck inclination.

3.1.3. Trunk inclination

Analysis of variance showed that weaving height had a highly significant effect on trunk inclination ($F = 58.63$; $p < .0001$). Weaving height +30 cm causes a more upright trunk posture (Figure 3c). The effect of seat type on trunk inclination was significant as well ($F = 21.03$; $p < .0001$). Conventional and high seats lead to a significantly more upright trunk posture as compared to the bench ($p < .014$) (Figure 3c).

3.1.4. Arm angle

Analysis of variance showed that weaving height had a highly significant effect on arm angle ($F = 150.96$; $p < .0001$). A higher weaving height causes a significant increase in arm elevation (Figure 3d). The effect of seat type on arm angle was only significant at weaving height +30 cm, in which a reduction of 5º occurred while using the high seat ($p < .014$) (Figure 3d).

3.1.5. Elbow angle

Analysis of variance showed that weaving height had a highly significant effect on elbow angle ($F = 156.56$; $p < .0001$). Weaving height +20 cm causes a significant less deviated elbow posture as compared to weaving heights +30 cm and +10 cm ($p < .014$) (Figure 3e). The effect of seat type on elbow angle was significant as well ($F = 4.69$; $p = .013$). Although elbow angle decreased considerably at weaving height +30 cm and the traditional seat type (bench), the paired t test showed no significant difference between the seat types at weaving height +30 cm.

3.2. Perceived Posture

Table 2 presents mean ratings for perceived posture of the neck, back, shoulders, elbows and knees in the nine experimental conditions.

3.2.1. Neck

The Friedman test demonstrated that differences in mean ratings for perceived neck posture in the nine experimental conditions were significant ($\chi^2 = 15.88$; $p = .044$). Weaving height +20 cm was the most favoured by the test subjects (Table 2). No effect of seat type was found.

TABLE 2. Mean Ratings for Perceived Posture of Different Body Regions in the Nine Experimental Conditions (Average Group Scores)

Experimental Conditions		Perceived Posture*									
		Neck		Back		Shoulders		Elbows		Knees	
Seat type	Weaving Height	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Conventional	+10cm	4.1	1.4	4.6	1.3	3.9	1.5	3.5	1.1	3.0	0.9
	+20cm	3.6	1.6	4.3	1.3	3.7	1.6	3.7	1.5	3.1	1.1
	+30cm	4.0	1.8	4.3	1.4	4.3	1.9	4.1	1.8	3.0	1.3
High	+10cm	3.8	1.4	4.1	1.5	3.7	1.2	3.3	1.3	3.4	1.2
	+20cm	3.7	1.4	4.0	1.5	4.0	1.6	3.2	1.3	3.4	1.2
	+30cm	4.3	1.5	4.5	1.6	4.9	1.7	4.0	1.5	3.3	1.2
Bench	+10cm	4.0	1.6	4.6	1.3	4.1	1.5	3.3	1.6	3.8	1.4
	+20cm	3.3	1.1	4.7	1.4	4.2	1.5	3.4	1.4	3.5	1.2
	+30cm	4.1	1.5	4.8	1.6	4.9	1.8	4.2	1.4	3.8	1.1

Notes. *Scale: 1—*very favourable*, 3—*favourable*, 5—*unfavourable*, 7—*very unfavourable*.

3.2.2. Back

The Friedman test indicated weak significant differences among mean ratings for perceived back posture in the nine experimental conditions (χ^2 = 14.4; p = .072). Analysis of variance showed that weaving height had no significant effect on perceived back posture, but revealed that seat type had a significant effect on perceived back posture (p = .035). Based on the results, conventional and high seats were favoured by the test subjects.

3.2.3. Shoulders

The Friedman test showed significant difference among mean ratings for perceived shoulders posture in the nine experimental conditions (χ^2 = 23.03; p = .003). Only weaving height had a significant effect on perceived shoulder posture (p = .002). Based on the results, weaving heights +10 cm and +20 cm were favoured by the test subjects (Table 2).

3.2.4. Elbows

The Friedman test demonstrated significant difference among mean ratings for perceived elbow posture in the nine experimental conditions (χ^2 = 22.12; p = .005). Only weaving height had a significant effect on perceived elbow posture (p = .001). Based on the results, weaving heights +10 cm and +20 cm were favoured by the test subjects (Table 2).

3.2.5. Knees

The Friedman test showed significant difference among mean ratings for perceived knee posture in the nine experimental conditions (χ^2 = 21.30; p = .006). In this case, only seat type had a significant effect on perceived knee posture (p = .004). Based on the results, the conventional seat was favoured by the test subjects (Table 2).

3.3. Localized Postural Discomfort

The results of postural discomfort in the five body regions and the whole body in the nine experimental conditions are given in Figure 4.

3.3.1. Neck

Analysis of variance showed that weaving height had a significant effect on neck discomfort (F = 4.12; p = .021). Weaving height +20 cm caused less neck discomfort as compared to weaving height +30 cm and +10 cm (p = .01) (Figure 4a). At weaving height +10 cm, when the high seat was used, neck discomfort decreased considerably. No effect of seat type was found.

3.3.2. Back

Analysis of variance revealed that seat type had a significant effect on back discomfort (F = 6.00; p = .004). The lowest and the highest back discomfort were reported while using the high seat and the bench, respectively (Figure 4b). The difference between the two seats is significant (p = .006). Weaving height had no significant effect on back discomfort.

3.3.3. Shoulders

Analysis of variance showed that weaving height had a highly significant effect on shoulder discomfort (F = 10.71; p < .0001). Weaving height +10 cm and +20 cm caused lower shoulder discomfort than weaving height +30 cm (p < .001) (Figure 4c). No effect of seat type was found.

3.3.4. Elbows

Analysis of variance indicated that weaving height had a significant effect on elbow discomfort (F = 9.79; p = .001). Weaving height +10 cm and +20 cm caused less elbow discomfort than weaving height +30 cm (p = .002) (Figure 4d). Seat type had no significant effect on elbows discomfort.

3.3.5. Knees

Analysis of variance revealed that seat type had a significant effect on knee discomfort (F = 5.58; p = .006). The lowest and the highest knee discomfort were reported while using the high seat and the bench, respectively (Figure 4e). The difference between the two seats is significant (p = .004). No effect of weaving height was found.

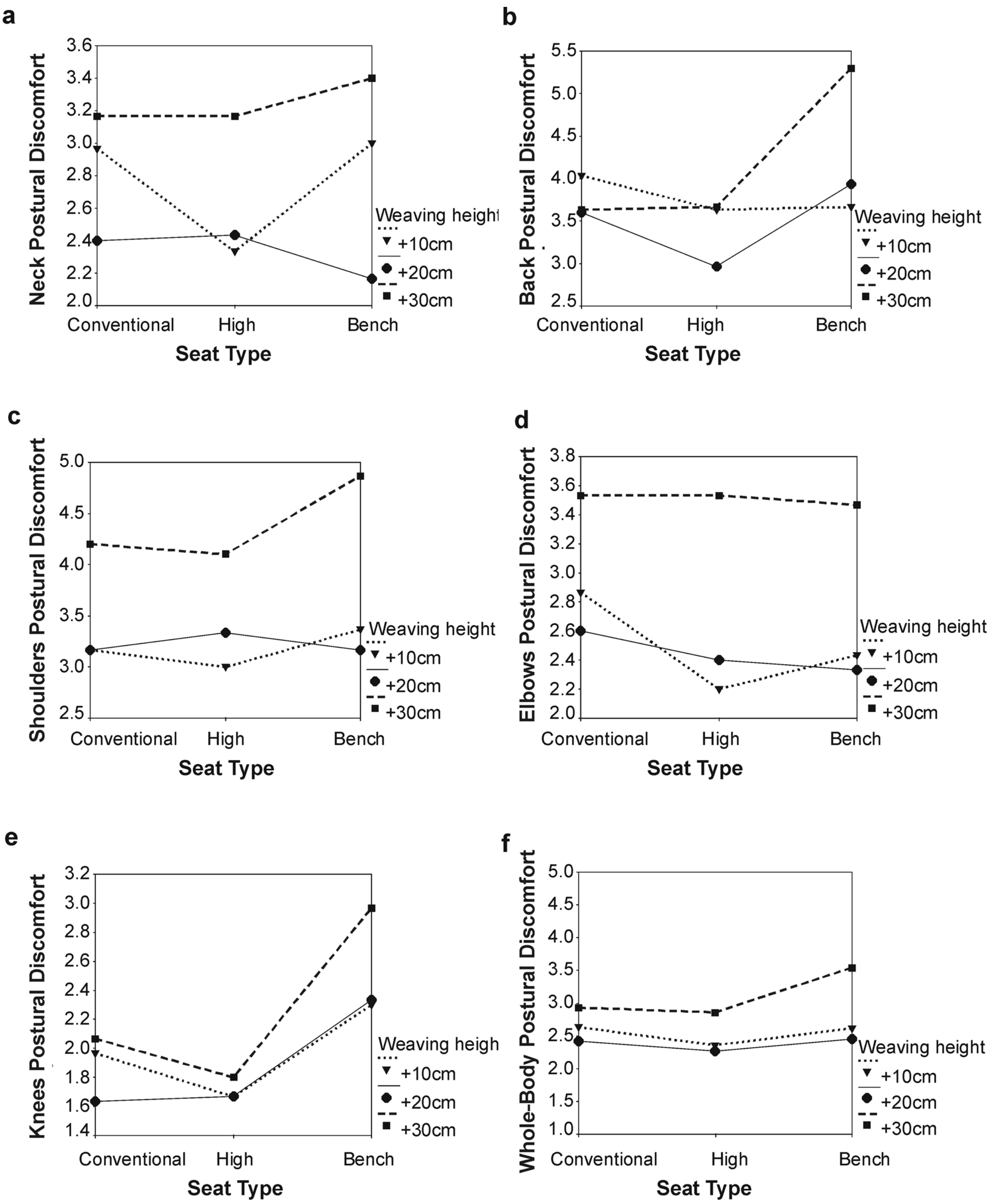

Figure 4. Postural discomfort of different body regions as well as of the whole body in the nine experimental conditions (average group scores): (a) neck, (b) back, (c) shoulders, (d) elbows, (e) knees, (f) the whole body. *Notes*. Scale: 0—*no discomfort*, 9—*very severe discomfort.*

3.3.6. The whole body

Analysis of variance showed that weaving height had a highly significant effect on whole body discomfort ($F = 7.99$; $p = .001$). The lowest and the highest discomfort were obtained at weaving height +20 cm and +30 cm, respectively. The difference between the two heights is significant ($p = 0.001$) (Figure 4f). Seat type had no significant effect on whole body discomfort.

3.4. Judgement on Workstation Adjustment

The results of the test subjects' judgement on workstation adjustment in the nine experimental conditions are shown in Figure 5.

3.4.1. Weaving height

Weaving heights +10 cm and +30 cm were considered on average *a little low* and *a little high*, respectively. Weaving height +20 cm was judged on average *right* (Figure 5a). Differences found between the weaving heights were significant ($p < .0001$).

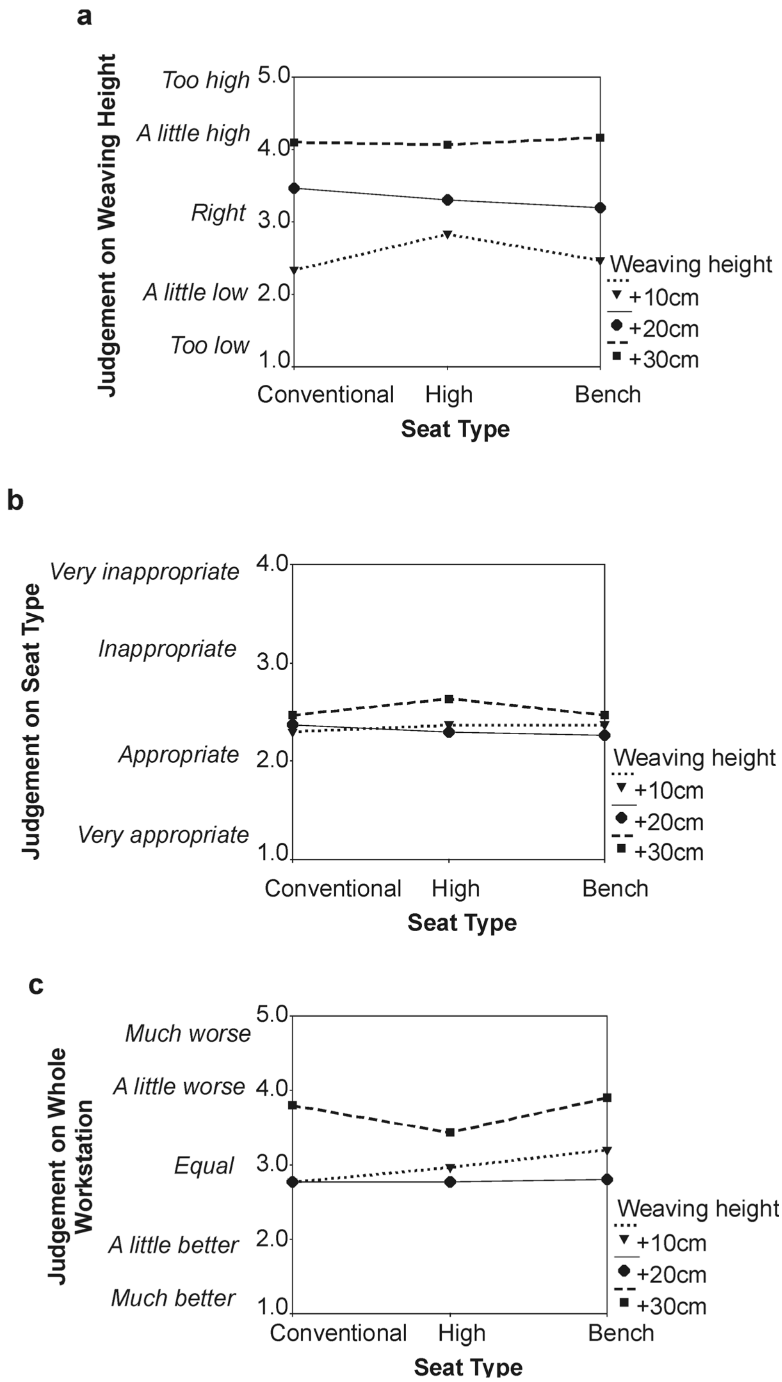

Figure 5. Judgement on workstation adjustment in the nine experimental conditions (average group scores): (a) judgement on weaving height, (b) judgement on seat type, (c) judgement on whole workstation adjustment as compared to own workstation in industry.

3.4.2. Seat type

As shown in Figure 5b, the test subjects' judgement on seat type ranged from *appropriate* to *inappropriate*. Conventional and high seats were judged *somewhat better*; however, no significant difference was found between the seat types.

3.4.3. Whole workstation adjustment

Statistical analyses revealed that weaving height had a highly significant effect on whole workstation adjustment judgement (F = 13.66; p < .0001). The best and the worst judgements were reported at weaving heights +20 cm and +30 cm, respectively (Figure 5c). The difference found between the two judgements was significant (p = .001). No effect of seat type was found.

4. DISCUSSION

4.1. Postural Variables

Figure 3 clearly shows several major effects of workstation adjustment on postural variables. Firstly, as weaving height increases, the head, neck and trunk get more upright. This is in agreement with the results of other studies on the effect of working height on head, neck and trunk postures [21]. Secondly, as weaving height decreases, shoulders get a more appropriate—and closer to natural—posture. This is in agreement with the findings of Freudenthal et al. [30]. Thirdly, weaving height +20 cm induces a better—and closer to neutral—elbow posture. As the body is a kinematic linkage, the position of hands determines the posture of wrists, elbows, shoulders, trunk as well as head and neck postures in visual activity [31]. A low visual-manual target causes head, neck and trunk flexion and a high target leads to upper arm and elbow flexion. It is, therefore, necessary to reach a compromise by which the posture of both regions is satisfied. In a weaving operation, weaving height +20 cm can be a suitable compromise in which the postures of the head, neck, trunk and shoulders do not seem to be severely deviated from neutral and the posture of elbows is appropriate.

Regarding seat type, as a traditional seat causes a more inclined trunk posture than the other two seats (Figure 3c), its usage is not recommended in a weaving operation. Both the conventional and the high seat can be recommended as they have overall positive effects on the posture of different body regions. However, it is worth noting that the high seat causes slightly less trunk inclination and increases the trunk-thigh angle. This results in increased lordosis in the lumber region [32, 33, 34, 35], which is considered an appropriate back posture.

4.2. Perceived Posture

The results on perceived posture (Table 2) showed that lower weaving heights (+10 cm and +20 cm) caused a more favoured posture in the neck, shoulders and elbows. In some cases, favour has inclined towards weaving height +20 cm. Regarding seat type, conventional and high seats resulted in more favoured posture in the back and knees.

4.3. Localized Postural Discomfort

The results indicated that the determinant factor for neck, shoulder, elbow and whole body discomfort was the weaving height. In all cases, weaving height +30 cm caused more postural discomfort in the mentioned regions as compared to weaving heights +10 cm and +20 cm (Figure 4). Weaving height +20 cm generally caused less postural discomfort; however, no significant difference was found between +10 cm and +20 cm.

Based on the results, the determinant factor for back and knees discomfort was seat type. The traditional seat caused the highest back and knee discomfort as compared to the other seats. The high seat provided a good situation leading to less back discomfort. Awkward posture of knees (cross-legged) could be the reason for knee discomfort while using the traditional seat.

4.4. Judgement on Workstation Adjustment

Based on the test subjects' judgement, the best weaving height was +20 cm. No certain seat type was favoured by the subjects as no significant difference was found among the seat types. Expanding the time of each experimental session or increasing the number of test subjects may lead to clearer results.

The results revealed that when weaving height was adjusted at +20 cm, the test subjects perceived the overall condition *a little better* to *equal* as compared to their own workstation in industry.

On the basis of the findings and with regards to the workstation parameters studied in this experiment, the following guidelines have been developed for adjustment of carpet hand-weaving workstations:

1. The weaving height should be adjusted at 20 cm above elbow height.
2. The 10º forward-sloping high seat is to be used in hand-weaving workstations. However, a conventional flat seat can also be used as it has a positive effect on the objective and subjective variables studied.

The guidelines are visualized in Figure 6.

5. CONCLUSION

It can be concluded from the results that in a weaving operation the determinant factor for head, neck and shoulder postures is the weaving height. Trunk and elbow postures were shown to be dependant on both design parameters investigated. The results have indicated that the determinant factor for weavers' perception on the neck, shoulders and elbows is the weaving height, and on the back and knees is the seat type. On the basis of the results, two guidelines have been developed to improve working posture: (a) the weaving height should be adjusted at 20 cm above elbow height; (b) a 10º forward-sloping high seat is to be used at a weaving workstation. It is believed that a weaving workstation adjusted based on the developed guidelines will improve the working posture and result in reduced postural stress on weavers' bodies and, consequently, reduced prevalence of musculo-skeletal symptoms.

In this study, no attempt was made to measure the effects of the developed weaving workstation on weavers' performance. Further field trials will be needed to test efficiency under real production conditions.

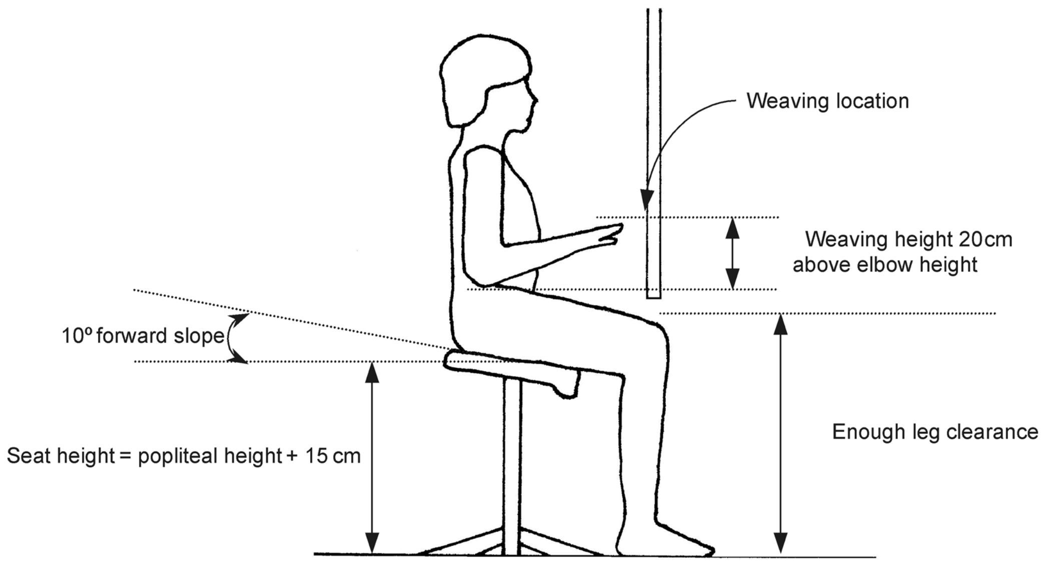

Figure 6. Guidelines for adjustment of a hand-weaving workstation.

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