CHAPTER 9

DESIGN OF ERGONOMIC SEAT FOR HANDLOOM WEAVERS

9.1 Introduction

Weavers are the backbone of the handloom sector and play an important role. Handloom weaving, a tedious task, is carried out manually by weavers (Khatoon and Iffat, 2022) and requires long hours of repetitive work (Telaprolu and Anne, 2014), sometimes over months. In Chapter 3, the challenges were identified and prioritized for the weaver's category, among which the poor health of workers is also highlighted as a major issue. This is because Weavers use different looms to produce the fabric, including pit, stand, and frame loom (Panda and Parida, 2019). The hand-operated looms require the weaver to sit at the loom and operate foot pedals that hang below (Durlov et al., 2014). For example, for saree weaving, an assigned weavers had to work long hours over months. While weaving, their motor and cognitive ability is the essence of weaving. The weavers adopt a variety of uncomfortable postures while performing a task that requires a lot of force and is very repetitive work for more than eight hours (Muthukumar et al., 2022). Continuous weaving while sitting over a plank of a pit loom is quite a timing job. Due to this highly repetitive work in uncomfortable sitting in the Indian handloom sector, 80% of workers suffer health-related problems. Among them, most of the weavers are suffering from musculoskeletal disorders (Koiri, 2020). According to Daneshmandi et al. (2017), musculoskeletal problems decrease worker productivity and lead to industry losses (Bhattacharya, 2014). A weaver with health issues may lose the opportunity to retain his job and earn for the family but also may like to switch his profession (Uddin et al., 2023). To sustain the sectors

and reduce the migration of weavers, it is necessary to study the health of weavers. The chapter presents the research objectives as follows:

- Identification of the weavers' MSD while using the old seat/plank and highlighting the major affected body parts.
- For the highlighted body parts of lower back and hips, designing and manufacturing a seat for weavers based on anthropometric data of weavers
- Evaluation of ergonomically designed seat with old seat through the comparison of MSDs.

The Varanasi handloom is one of the oldest textile centers in India (Saha and Sen, 2023), and this sector has national and international importance in manufacturing the saree. In Varanasi, most weavers use the pit loom (Singh and Kumar, 2018), which does not have an ergonomically designed seat. The weavers are sitting on the plain wooden plank, as shown in Figure 9.1. This leads to MSD pain. So, the study's objective is to design an ergonomic seat for the pit loom weavers. This study was carried out in three phases, as shown in Figure 9.2 and described in the following sections.

Figure 9.1: Wooden plank seat for pit loom

9.2 Phase I

In this phase, the current sitting arrangement of weavers was studied. Following section describes the methods and the findings.

9.2.1 Material and Methods

In the first phase, the weavers of the Varanasi handloom sector were contacted to participate in the study. A total of two hundred fifty-three weavers were contacted, and fifty-six weavers agreed to the study. The demographic and working experience of the agreed weavers is shown in Table 9.1. The sample size for this study was decided based

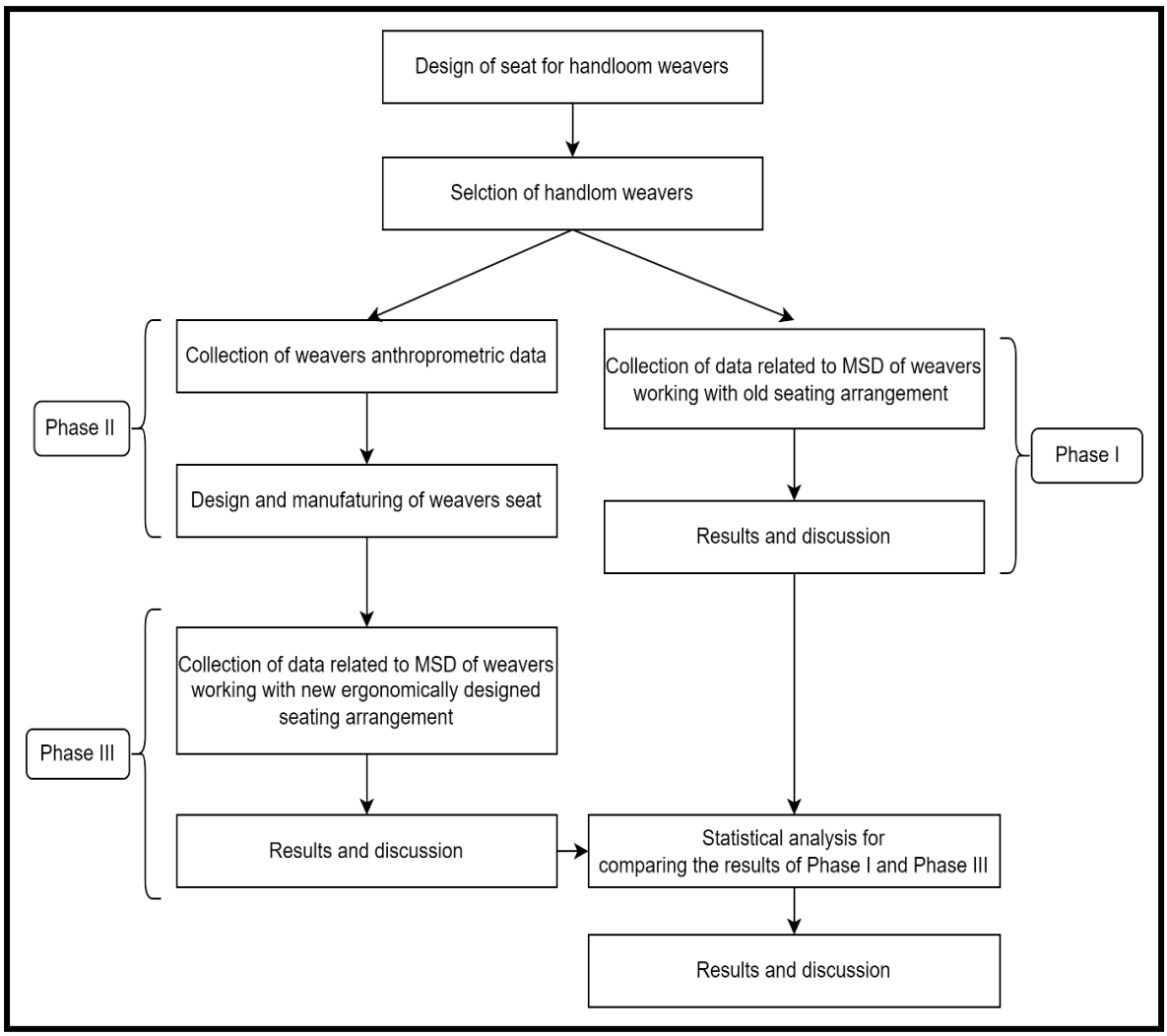
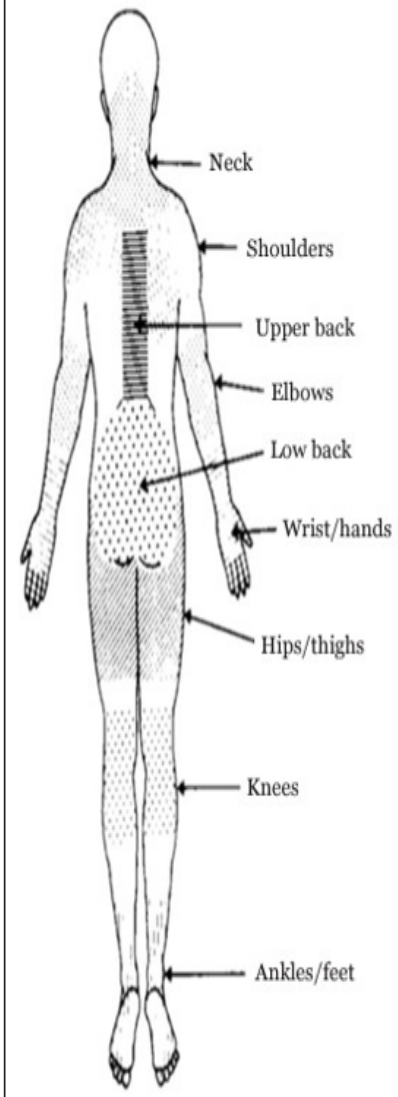


Figure 9.2: Methodology

For the MSD data collection of the weavers, the Nordic MSD questionnaire was used, as discussed in section 2.8.4; it is used by the different researchers because of the reliability and validity of the questionnaire in different sectors. The study due to i) Muhamad Ramdan et al. (2020), who used a Nordic questionnaire for the collection of MSD data of 40 Samarinda sarongs weavers, and ii) Khan and Singh (2018), who used 51 participants by using a Nordic questionnaire to examine the musculoskeletal problems of sahayaks. This study also used the Nordic Musculoskeletal Questionnaire (NMQ) section with the personal details section to collect data from weavers. The NMQ is a general questionnaire covering major body parts and can hardly lead to mistakes (López-Aragón, 2017). Many attempts to validate this NMQ lead to more or less satisfactory results. So, this NMQ has been used in its current form in this study (López-Aragón, 2017).

The NMQ sample is shown in Figure 9.3. The weavers were asked to rate the pain in the body during the last seven days of the work on a scale of 0 to 4, where (0= no pain, 1= very low pain, 2= moderate pain, 3= high pain, 4= very high pain).



During the last seven days, have you had trouble in (Such as aches, pain, discomfort, and numbness) in:			If yes, select 1- Very low pain 2- Moderate pain 3- High pain 4- very high pain
Neck	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Shoulder	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Upper back	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Elbows	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Wrist/hands	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Lower back	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Hips/thighs	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Knees	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯
Ankles/feet	Yes ☐	No ☐	1 ◯ 2 ◯ 3 ◯ 4 ◯

Figure 9.3: Nordic questionnaire

Table 9.1: Demographic data of the weavers

Variables	**Mean (Standard Deviation)**	**Range**
Age (years)	39.9(10.3)	23-59
Weight (kg)	59.4(7.4)	48-80
Height (cm)	171.5(7.3)	155.4-185.9
Experience (years)	14.2(6.4)	5-27
Daily working time (h)	9.2(1.4)	6-14

9.2.2 Results and Discussion.

The survey results show that the most commonly affected region among 82% of weavers was the lower back, in which 13% face very high pain, 25% face high pain, and 36% moderate pain. The second highest body pain region for 79% of weavers is hips/thighs, which includes 4% of weavers facing very high pain, 18% facing high pain, and 41% facing moderate pain. The partwise pain percentage and the intensity of pain are shown in Figure 9.4. Eighty-two percent of weaves had experienced MSD pain at some point of time in the last seven working days.

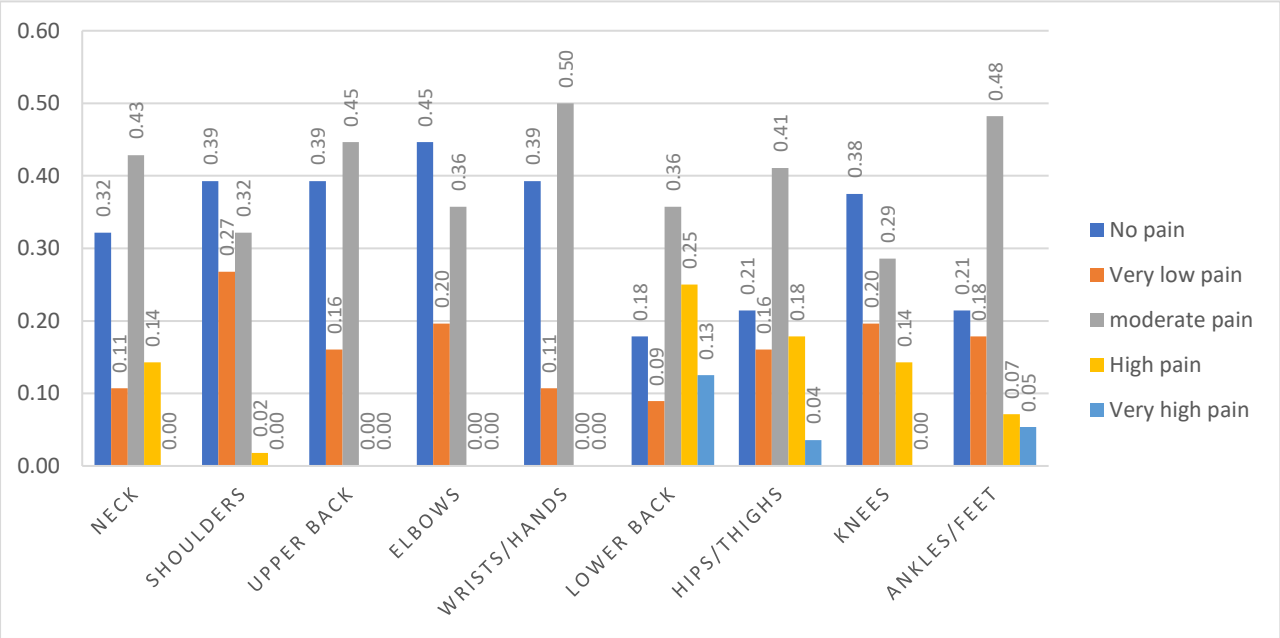


Figure 9.4: MSD data of weavers using wooden plank (Seat)

Figure 9.4 shows that most weavers have low to high pain in the ankle, knees, thighs/hips. A properly designed seat may be used to reduce the pain level in these body parts of weavers. So, a proper sitting arrangement for weavers is required, and an effort was made to this extent in phase II.

9.3 Phase II

In phase II, a plank was designed based on anthropometric data of weavers for their proper sitting over a longer duration of repetitive weaving work.

9.3.1 Materials and Methods

The weaver's anthropometric data was collected in this second phase to design and manufacture ergonomic seats/planks for weavers. Dianat et al. (2013) used anthropometry data to design furniture to reduce the musculoskeletal problems of students. Similarly, Kang et al. (2023) also used body dimensions to design the automotive seat. The type of anthropometric measures considered for handloom weavers are shown in Figure 9.5. Figure 9.6 shows the collection of the data of weavers.

Along with the scientific equipment, an adjustable prototype seat has been used to measure weavers' body shape. Figure 9.7 shows the adjustable seat developed for measuring weavers' shapes while sitting on the loom. Figure 9.8 shows the weaver's prototype seat installed according to the weaver's requirements. The weaver's body shape is collected to propose new dimensions for the weaver's seat.

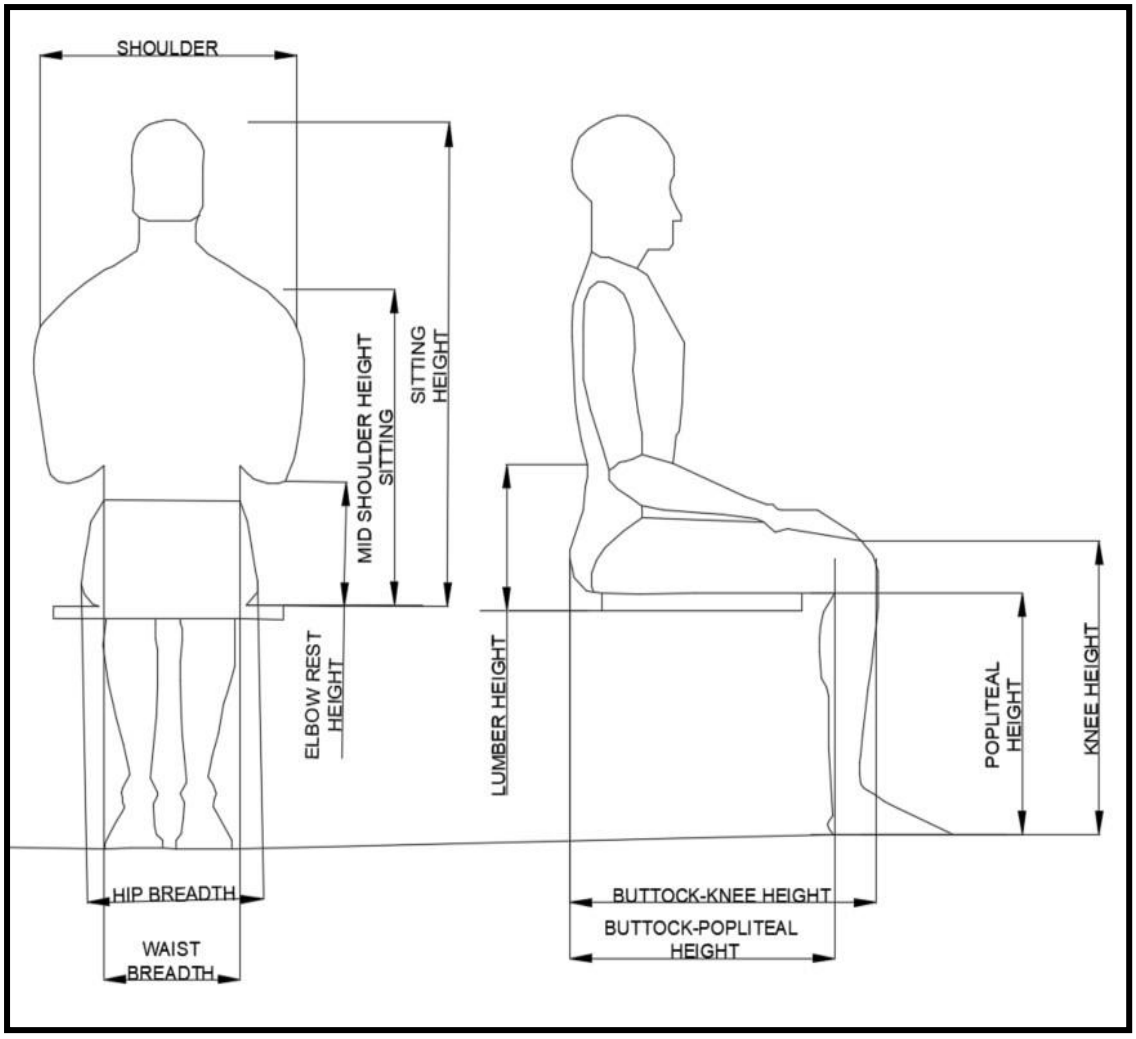


Figure 9.5: Anthropometric data representation adopted from Mahmoudi and Bazrafshan (2013)

Figure 9.6: Collection of arthrometric data of weavers

Figure 9.7: An adjustable prototype seat for measuring the weaver's seating shape

Figure 9.8: Adjusting prototype seat according to weaver's comfort

9.3.2 Results and Discussion

The measured body dimension was analyzed by using Microsoft Excel 2019. The anthropometric data of the 56 weavers with 5^{th}, 50^{th}, and 95^{th} percentile, their mean and standard deviation, is shown in Table 9.2.

Table 9.2: Anthropometric data of handloom weavers (N=56)

Sr. No.	**Body dimensions * (Cm)**	**5^{th} percentile**	**50^{th} percentile**	**95^{th} percentile**	**M(SD)**
1	Shoulder height	54.86	61.32	63.57	60.48 (3.0)
2	Knee height	49.38	54.32	57.12	54.47 (2.3)
3	Popliteal height	40.23	44.26	46.54	44.34(1.9)
4	Buttock-knee	49.38	54.75	57.12	54.45(2.3)
5	Popliteal depth	40.23	44.26	46.73	44.42(1.9)
6	Lumber height	22.86	25.15	26.45	25.11(1.0)
7	Shoulder length	40.23	44.26	46.61	44.40(1.9)
8	Waist length	30.18	33.19	34.91	33.28(1.4)
9	Waist depth	18.29	20.12	21.16	20.17(0.9)
10	Buttock length	32.92	36.21	38.08	36.30(1.5)
11	Armrest height	21.95	24.14	25.39	24.20(1.0)

*The terminologies are according to Mahmoudi and Bazrafshan (2013)

* M= Mean, SD= Standard deviation

The weavers were allowed to sit on the prototype adjustable seat while using the loom, and seat adjustments were made and recorded according to the weaver's requirements with their feedback on the back support height, thigh support, and body curve shape. Figure 9.9 shows the plot of the body curves of the weaver's seat, where X and Y axes are represented in Centimetres. The weavers' 50th percentile of the body shape measurements is considered for the ergonomic seat design.

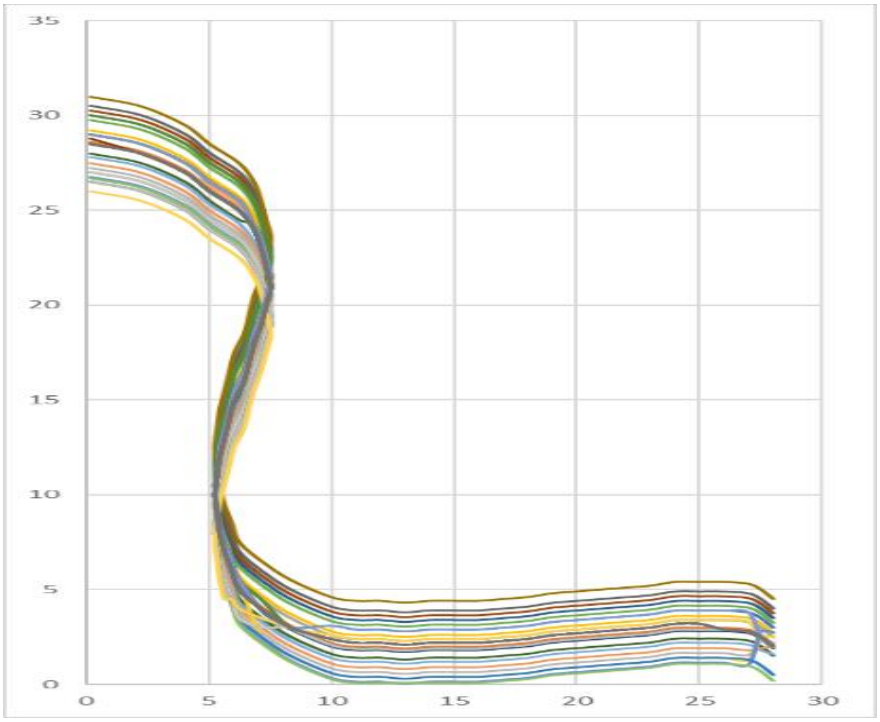


Figure 9.9: Body contours of weavers while seated on prototype seat

The dimensions of the weaver seat were proposed by considering the weavers' anthropometric data and loom size and are shown in Table 9.3. The proposed seat was designed using the AutoCAD software and shown in Figure 9.10. Next, the designed seat for weavers was manufactured of wooden material, as shown in Figure 9.11. This seat was then used to collect the data for the next phase.

Table 9.3: Dimensions of the New seat/plank for pit loom weavers

Parameter	**Symbol**	**Value**
seat height Adjustable	A	Pit height + (1-10cm)
seat pan depth	B	28 cm
seat pan width (pit width)	C	111cm
seat pan tilt foreword Adjustable	D	**0° – 10°**
Lumber support height	E	25cm
Lumber support width	F	53cm
Lumber support backrest angle adjustable	G	90 -110°
seat pan depth adjustable	H	1-10 cm
Lumber support height adjustable	I	1-5 cm

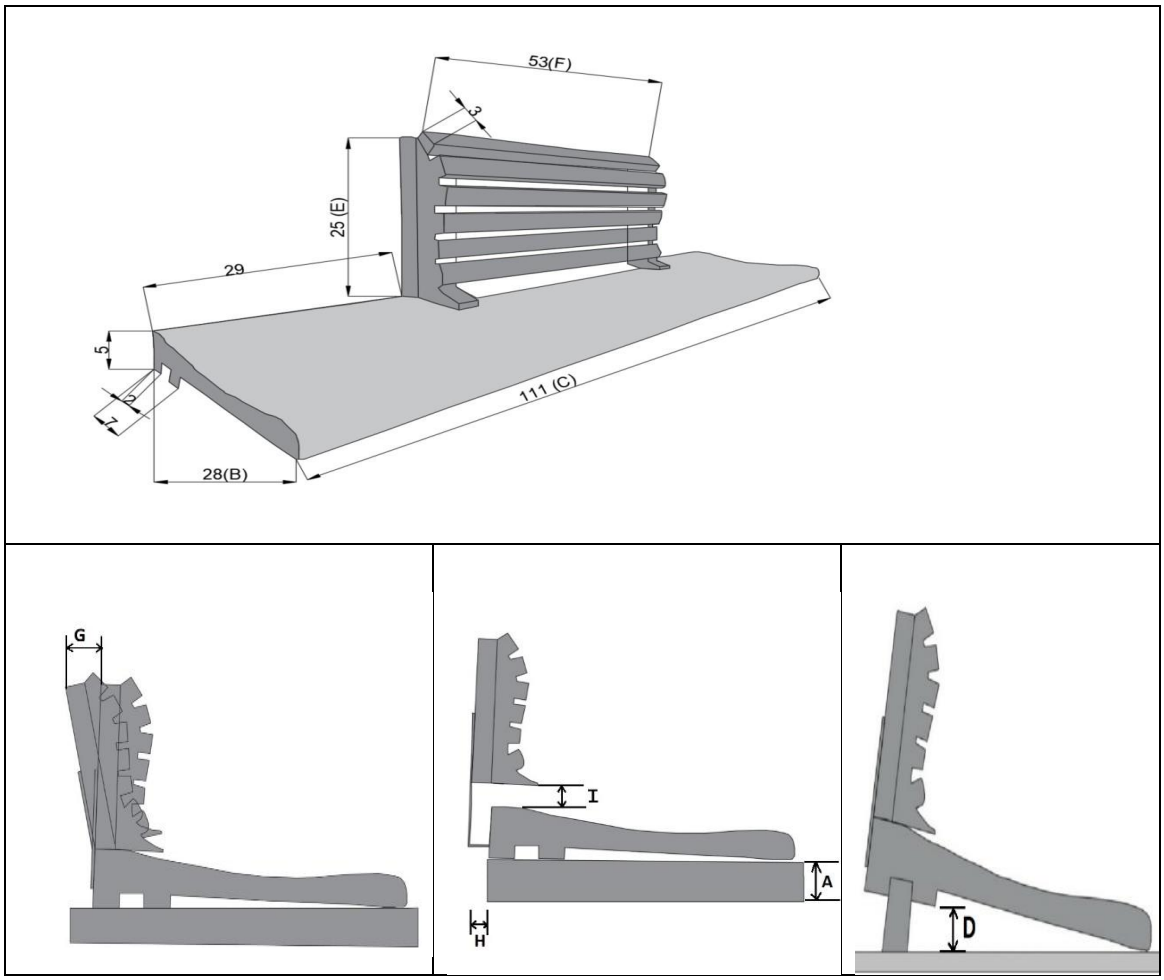


Figure 9.10: Design of ergonomically designed seat for handloom weavers
*All dimensions are in cm (Centimetres)

Figure 9.11: The ergonomically manufactured seat for the handloom weavers

9.4 Phase III

In this phase, the designed and manufactured seat/plank with back support was implemented in the pit loom, and weavers were allowed to work with it. The Data was collected under this situation in the same fashion as was done in Phase I.

9.4.1 Materials and Methods

In the third phase, an ergonomically designed seat, manufactured using wooden material (Figure 9.11), was used by each weaver for seven days, as shown in Figure 9.12. After completing the seven days' work, a Nordic Musculoskeletal Questionnaire (NMQ) (Figure 9.1) was used, as shown in Figure 9.1, for measuring MSD pain. The same weavers were asked to rate the pain in the body during the last seven days of the work, very similarly to the process of Phase I.

Figure 9.12: weavers using the new ergonomically designed seat

9.4.2 Results and Discussion

The survey results show that 75% of weavers reported the lower back with 14% facing high pain and 45% facing moderate pain. Whereas 73% of weavers found the second highest body pain in the hips/thighs region, with 2% of weavers having high pain while 25% had moderate pain. The body partwise pain percentage and pain intensity are shown

in Figure 9.13. Seventy-five percent of weaves had experienced MSD pain at some point of time in the last seven working days.

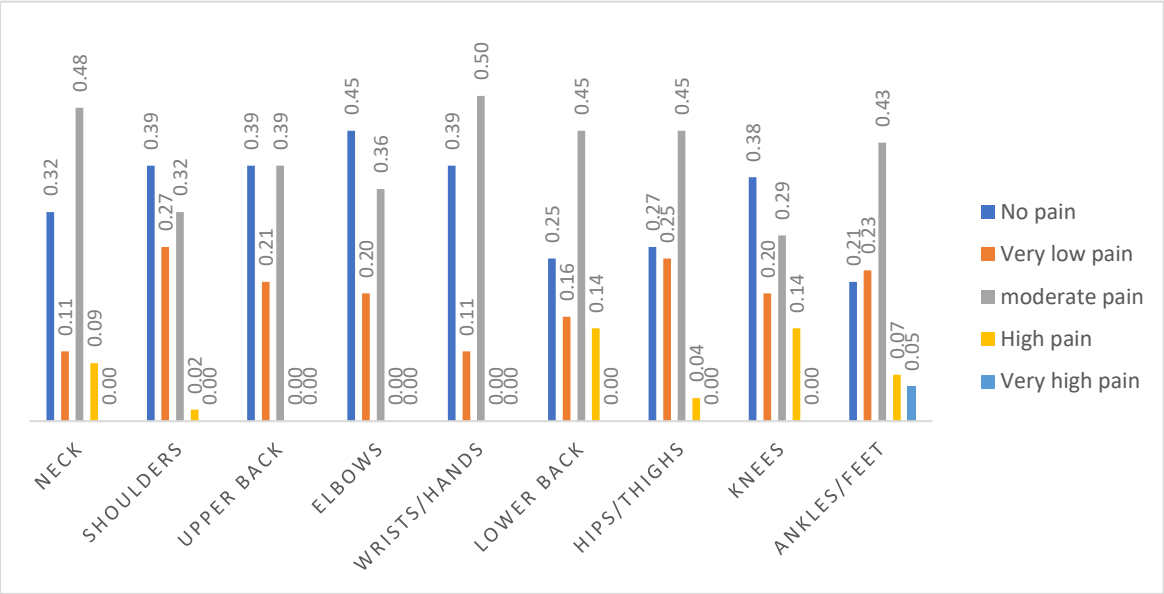


Figure 9.13: MSD data of weavers using the new ergonomically designed seat

The next section presents the comparison of the results of the data collected in Phase I and II.

9.5 Statistical analysis for comparing results of phase I and Phase III MSD of weavers

9.5.1 Materials and Methods

In this study, one-way analysis of variance (ANOVA) was used to compare the MSD pain of the old seat (wooden plank) and the new ergonomically designed seat/plank. According to (Kushwaha et al., 2023), the one-way ANOVA method is used to compare the significant differences between the groups. Mills et al. (2020) used one-way ANOVA to compare the MSD of dental professionals. Falahati et al. (2019) used one-way ANOVA analysis to predict MSD among automotive workers. SPSS 23 software was used to perform ANOVA to compare the results with a p-value of 0.05. Various hypotheses were

formulated and summarised in Table 9.5. Table 9.5 shows a hypothesis as H_{oi}: null hypothesis for part *i* and is read as "there is no significant difference of pain in i^{th} body part when using an old plank and newly designed plank. For example, H_{o7} is the null hypothesis read as "there is no significant difference in pain comparing the use of old design plank with a new design plank." The last column, Table 9.4, also shows whether the null hypothesis is accepted or rejected based on the results of ANOVA presented in Table 9. 5.

Table 9.4: Hypothesis and its results

			New Design Related pain									H_{oi} accepted or rejected.
			N	S	UB	E	W/H	LB	H/t	K	A/F	
OLD Design Related pain	H_{o1}	N	✓									accepted
	H_{o2}	S		✓								accepted
	H_{o3}	UB			✓							accepted
	H_{o4}	E				✓						accepted
	H_{o5}	W/H					✓					accepted
	H_{o6}	LB						✓				rejected
	H_{o7}	H/T							✓			rejected
	H_{o8}	K								✓		accepted
	H_{o8}	A/F									✓	accepted

Table 9.5: Results of One-way ANOVA

		Sum of squares	**Std. deviation**	**df**	**Mean square**	**F**	**Sig.**
Neck	Between groups	.080		1	.080	.071	.790
	Within groups	123.911	1.056	110	1.126		
	Total	123.911		111			
Shoulders	Between groups	.000		1	.000	.000	1.000
	Within groups	87.857	.889	110	.799		
	Total	87.857		111			
Upper back	Between groups	0.80		1	.080	.097	.756
	Within groups	90.839	.905	110	.826		
	Total	90.920		111			
Elbows	Between groups	.000		1	.000	.000	1.000
	Within groups	89.107	.895	110	.810		
	Total	89.107		111			

Wrists/ Hands	Between groups	.000		1	.000	.000	1.000
	Within groups	98.714	.943	110	.897		
	Total	98.714		111			
Lower back	Between groups	9.143		1	9.143	6.945	.010
	Within groups	144.821	1.177	110	1.317		
	Total	153.964		111			
Hips/ Thighs	Between groups	4.723		1	4.723	4.596	.034
	Within groups	113.054	1.030	110	1.028		
	Total	117.777		111			
Knees	Between groups	.000		1	.000	.000	1.000
	Within groups	133.679	1.097	110	1.215		
	Total	133.679		111			
Ankles/ Feet	Between groups	.080		1	.080	.069	.793
	Within groups	127.696	1.072	110	1.161		
	Total	127.777		111			

9.5.2 Results and Discussion

The results of one-way ANOVA for comparing the use of old plank and new ergonomically designed seat/plank are shown in Table 9.5.

Tables 9.4 and 9.5 show that the hypotheses H_{o6} and H_{o7} are rejected, meaning by that pain in the lower body and hips/Thighs parts are significantly different with their p as 0.01 and 0.034, respectively. The rest of the null hypothesis are accepted for body parts other than Lower Back and Hip/Thighs, i.e., there is no significant difference of pain in the rest of the body part while comparing the two designs as p values are greater than 0.05. Table 9.6 shows the factual comparison of pain in the weaver's lower back and hips/thighs with the old design and new design. Notably, the effect of the seat/plank design was seen only on the lower back and hips/thighs. Table 9.6 presents a detail of these changes.

Table 9.6: Details of pain in lower back and hips/thighs region of weavers

	Lower back pain (%)			Hips/Thighs pain (%)		
	old seat	**new seat**	**change**	**old seat**	**new seat**	**Change**
No pain	0.18	0.25	-38.89	0.21	0.27	-28.57
Very low pain	0.09	0.16	-77.78	0.16	0.25	-56.25
Moderate pain	0.36	0.45	-25.00	0.41	0.45	-9.75
High pain	0.25	0.14	44.00	0.18	0.04	77.77
Very high pain	0.13	0	100.00	0.04	0	100

Table 9.6 clearly shows that cases of no pain, very low pain and moderate pain has increased over 7 days of operations while high pain and very high pain has reduced drastically. This shows that the effectiveness of the designed plank with back support.

9.6 Conclusion

The study's objective is to reduce the MSD pain of the weavers. A preliminary study conducted by using a Nordic questionnaire revealed that handloom weavers and has highlighted that weavers were suffering from MSD pain, with the most affected body parts are the lower back at 82 percent and hips/thighs at 79 percent. Using anthropometric data, a new ergonomic seat was designed and manufactured for handloom weavers. MSD pain data were collected using a Nordic questionnaire with old plank and newly designed seat/plank with a study period of seven days. The MSD data with an old plank for moderate, high, and very high pain showed that 73% weavers suffer from lower back pain, and 63% suffer from the hips/thighs. The use of the new design has reduced this to 59% for back pain and 48% for hips/thigh pain, resulting in 19.17% and 23.80% decrement in the weaver's lower back and hips/thigh pain. A statistical method was used to validate the results. The statistical analysis shows that there is a significant difference in the lower back

and hips/thighs while comparing the old design with a new design. This proposed design of seat/plank with back support was supportive in the reduction of MSD of handloom weavers, especially in lower back and hip/thigh pain. This proposed seat/plank design can be used by master weavers, independent weavers, and weavers in cooperative societies to increase the comfort of weavers. This ergonomically designed plank does not reduce the pain level in other parts of the weavers. Developing the complete loom design with the proposed seat/plank for the handloom weavers can be the future extension of this work to decrease MSD pain in other parts of the weavers.