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Ashish Kumar Singh, Makkhan Lal Meena & Himanshu Chaudhary

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Measuring Static Muscular Strength among Female Operatives': A Cross-Sectional Comparison in Different Handicraft Occupations

Ashish Kumar Singh*, Makkhan Lal Meena, Himanshu Chaudhary

Department of Mechanical Engineering, Malaviya National Institute of Technology, Jaipur, India

Email: singh.mechanical@yahoo.com
*Corresponding Author

Abstract

Purpose: Loss of static muscular strength is the most common work-related problem among handicraft workers involved in hand-intensive jobs. A cross-sectional comparative assessment was carried out to determine the muscular strength among the workers involved in the manufacturing of three different crafts, i.e., weaving, hand block printing, and imitation jewelry *Methods:* 120 female operatives' were selected, and digital grip dynamometers were used to measure their maximum handgrip and pinch strength. *Results:* The static muscular strength varies significantly among the different occupational group of workers. The difference in grip strength in the right and left hand unravel that the exposure to hand tools for a prolonged period plays a vital role in muscle strength. These findings indicate that static muscular strength varies significantly due to repetitive use of hand tools. The observed values of muscle strength in the dominant hand were significantly lower in jewelry workers while block printing workers had the highest strength. *Conclusion:* The decrement in pinch grip strength was evident due to long cycle

repetitive pinching movements of distal phalanx during hand knotting and pearl drilling. This study proposes the need for ergonomically designed hand tool interventions that may reduce the accumulation of loss in static muscle strength.

Keywords: static muscle strength, handgrip, pinch grip, carpal tunnel syndrome, ergonomics, handicrafts

1. Introduction

Handicraft manufacturing is a traditional artistic activity and shares some common work characteristics such as the involvement of lower-arm, hand-eye coordination and fine dexterity of the worker [1]. Depending on the nature of the job and design of hand tool, handicraft operatives can be exposed to awkward posture, forceful gripping, high repetitiveness, and hand-arm vibration (HAV) hazard. These variables are directly associated with the symptoms of cumulative trauma disorder (CTD) [2-5]. Safety guidelines for the upper extremity could prevent workplace injuries and reduce the risk of CTD [6]. This research is concerned with the relative causes for the loss of static strength that are associated with holding the poorly designed hand tool or materials against a mechanical process.

Handicraft work is a challenging occupation in which workers may suffer from various work-related problems. Several studies carried out in the past have primarily assessed musculoskeletal disorders (MSDs), physical conditions, and physiological factors among the handicraft workers [7-11]. Besides these factors, the design of hand tools contributes to increasing the risks of carpal tunnel syndrome (CTS). Design of hand tools developed the foundation to ease the efforts of the workers, thus resulting in lower MSDs among them [12, 13].

The Indian handicrafts industry is part of the small manufacturing industries, and a significant part of the Indian population is dependent on handicraft sector. It possesses around

50% of the national product by informal sector which makes it the largest producer and exporter in the international market [14]. Exports of art-wares have a massive market demand mainly in American and European markets [15, 16]. The export of Indian handicrafts rose exceptionally, over the period of establishment (1986–1987) of the export promotion council for handicraft [17]. According to the provisional data available the exports of handicrafts have shown an increase of USD 231.17 million, i.e., the exports increased by 13.5% in one year [18].

Roughly over 0.5 million workers are presently employed in the Indian handicrafts industry, and it is likely to generate more employment opportunities, mainly in the rural regions of the country [19]. According to the National Statistical Commission, 90% of the country's workforce are accounted for by the informal economy [13, 20]. The country supports 7 million people and contributes a substantial part of the total workforce from India [21]. With a gradual influx of commercialization in this industry, labor-use arrangements have also undergone a change. From an occupational point of view, the workers often engaged in rigorous hand-intensive work and spent long working hours to obtain target specific productivity (produce more output in a short period of time) [22].

Weavers, block printing, and imitation jewelry workers are often recognized as the occupational groups that are most sought-after female workers because it can be set up within the household or nearby workshops. Hence, lack of occupational health and safety practices are common among the operatives in these handicraft professions. Women with responsibilities of running the home and taking care of the family, find it convenient to do part-time jobs near their homes [23]. Moreover, these jobs were paid less compared to other work. Therefore, it was observed that the work was not popular with male workers working in the same handicrafts industry.

Most of the previous literature related to the carpet industry workers of India primarily focused on the occupational health problems during weaving [24-29]. Investigations concerned with the working environment of weavers during different seasons in the state of Kashmir and Madhya Pradesh (India), were carried out. They brought attention that these workers were prone to several health risks during different seasons [30, 31]. However, the studies related to work system interventions in the carpet industry are available to a limited extent [29, 32].

A recent study used questionnaire survey on 120 workers of four different handicraft trades reported that the significant factors which influence the quality of work life are working environment, job security and cooperation with co-workers [33]. In their continued study, they investigated MSDs among the workers in hand block textile printing industry and recommended that some suitable risk reduction and health promotion programmes should be implemented to enhance safety and well-being among the workers [34].

Previous literature also showed that the investigators in the recent years have focused on the assessment of visual demands, muscular and neurological examinations, range of motion, and, muscle strength tests in the imitation jewelry work [35-38]. A study on woodcarving workers reported about the occupational health risk problems that include eyesight problems, backache, gastric ulcer, asthma, and skin problems during carving [39]. Few related studies also suggested that the woodworkers are highly prone to respiratory tract problems due to exposure to wood dust which may cause respiratory symptoms such as chronic bronchitis, cough, and breathlessness [40-42]. Musculoskeletal risk factors have also been found to be prevalent among the workers involved in blue pottery, handloom and gota patti craft [22]. Furthermore, the lack of rationale for the use of the methods to characterize ergonomics challenges during handicraft work in different informal sectors suggests that the area needs to be explored.

Primary concerns of these previous longitudinal studies were only on assessment of work-related disorders among the handicraft workers. A literature review indicates that no significant research has carried out so far in the handicraft sector from a static muscular strength perspective, despite heterogeneous tools used. A cross-sectional study advocates the evaluation of muscle grip strength as a diagnostic tool for assessing the outcome of hand injury [43]. Moreover, the work exposure of previous occupations has a direct association with the present grip strength of the worker [44]. In a longitudinal study of 1107 recently-hired young workers, it was reported that the loss of grip strength alone was an inappropriate predictor of assessing upper extremity MSDs among newly recruited workers [45]. Grip strength is one of the essential characteristics of a healthy hand [46]. Moreover, it has also shown a significant difference between healthy and subacute patients [47]. A few studies have shown that the exposure to CTS and hand-arm vibration among workers engaged in hand-intensive jobs suffered lower grip strength [29, 32, 48].

Unfortunately, the inadequate literature leads to a need for assessing static muscular strength among the workers involved in the different crafts trades. Therefore, it was thought that this study shall estimate the muscle strength among three handicraft occupations. The objective of the present research is to determine some essential static muscular strength, such as hand grip strength, pinch grip strength (tip, key, and palmar grip) of female workers coming from different occupations involving highly repetitive movements. This study hypothesizes that the strength values for handicrafts operatives in different vocations, exposed to different hand tools are relatively different from each other. In low-income countries like India, informal sectors are not willing to use expensive tools, and that makes it challenging to implement the research interventions to overcome the worker's problems [49]. This study assesses the ergonomic aspects at the grass-root level and proposing the insight to develop a better design of hand tools and workstation.

2. Methods

2.1. Selection of Participants

The present cross-sectional study was carried out from August 2017 to October 2017. The selection of female participants was based on their respective occupations. They were divided into three groups as per their occupation, viz., carpet weavers, hand block printing workers and imitation jewelry workers. These 120 asymptomatic female participants were mainly engaged in handicraft work in three different vocations. Of these participants, 45 were carpet weavers, 45 hand block printing workers, and 30 imitation jewelry workers. They were randomly selected from 16 handicraft workshops which were situated within the urban and rural area of Jaipur and its nearby districts.

The average work experience of the participants in the present occupation was 11.89 ± 7.14 years. Minimum one year of work experience in the same job and right-hand dominance was the inclusion criteria for this study. Only dominant right-hand workers were selected for the survey for minimizing any discrepancy in overall statistical significance or familywise error rate due to hand dominance. They were having no history of upper extremity disorders and chronic and acute diseases. The University Institutional Review Board approved all experimental procedures, and all female workers were provided written informed consent before the participation.

Since the workshops were situated at different locations; it was not possible to invite all the workers at the institute laboratory. The anthropometry and static grip strength tests of the experimental cohort were collected at their respective work locations. The study was designed in a way that every participant's data was recorded in a similar way, unfatigued prior to work. Therefore, they were asked to come to the workshop before the work shift. Repeated surveys were done over two months to obtain the data. The data were collected from 07:00 to 09:00 at the workshops.

The demographic description of the participants is depicted in tabulated form in Table 1. The mean age of the women participants was 29.81 ± 7.36 years (Table 1). The nutritional status of the participants was assessed by their body mass index (BMI) values [50], and it was found that the mean value of BMI (20.13 ± 3.53) was within the normal range. From data analysis, it was found that most of the demographic variable distribution of participants were not normal. For example, a skewness of 0.43 (SE = 0.40) and 0.68 (SE = 0.45) and a kurtosis of –0.42 (SE = 0.85) and –0.68 (SE = 0.81) was found for the age and experience in weavers. Whereas, the BMI and body surface area (BSA) were found to be normally distributed for a chosen level of significance ($p>0.05$), for all the cases.

(Insert Table 1 here)

2.2. Tasks Involved in Handicraft activities

During this study, the static muscular strength was evaluated among the workers involved in three different crafts trades, viz. carpet weaving, block printing, and, imitation jewelry (pearl hole drilling/setting). The details of tasks involved in these occupations have been discussed later in the text.

Hand-knotted weaving involves stooping and squatting postures adopted by the weavers during prolonged weaving task. During weaving, the weavers sat next to each other and wove the carpet as per the provided map using conventional hand tools. These hand tools include weaving knife, weaving comb, and a beater. The weaving knife is used to cut the knot after the completion of each knot. The weaver holds the knife throughout the process of knotting which leads to forced fisted cylindrical grasping in their dominant hand. The weaving comb and beater are used after finishing a row of knots and weft. The weaving of a carpet usually takes several months, depending upon the size, and as per urgency of the customer. Weaving requires enormous concentration and long duration of sitting. Long hours of same squat posture could cause musculoskeletal disorders in different body regions. The process requires repetitive movement of digits and wrist that could be directly associated with cumulative trauma disorder [29].

Hand block printing usually carried out in standing position and prints were made using a block die tool. It is used to replicate the shape of die block on the cloth extending high static muscular loads on the forearm. The worker holds the tool throughout the process which leads to forced pinch grasping in their dominant hand. Nevertheless, the block printing requires extensive repetitiveness and reaching out to punch the die into the cloth on the work table with unusual, awkward postures.

Pearl hole drilling/setting is a part of making imitation jewelry. The worker sits in a squat posture holding the pearl to be drilled and placing it on the powered drill to make a hole. The drill bit of size greater than the size of the necklace thread was forced against the pearl creating hand vibration, and noise expose. The vibration is transmitted from the finger to the hand while holding the pearl to a correct position.

2.3. Grip Strength Test

The test was administered using the Baseline® hydraulic hand and pinch grip dynamometers. The objective of the test was to monitor and evaluate the static muscle strength among the groups of female workers in working in three different handicraft occupations.

2.3.1. Hand Grip Strength Test

The objective of the test was to monitor and evaluate the hand grip strength. To undertake the examination, Baseline® hydraulic hand dynamometer (Fabrication Enterprises Inc., United States) was used. According to the American Society of Hand Therapists, the second handle position (grip span of 4.8 cm) of the hand dynamometer was recommended to be the best level for grip evaluation [51, 52]. In a study by Trampisch et al. (2012), the results showed accurate grip strength measurements taken at a single standard handle position [53]. Therefore, the second handle position as the standard position for measuring grip strength was used. The participants were tested while sitting on a chair without armrest. The sitting posture included their hips and knees flexed at 90°, elbow flexed at 90°, forearm rotation at 0° and wrist at the neutral position [54]. The participant using their dominant hand [55] applies as much grip pressure as possible on the dynamometer for 5 s. The readings were recorded three times, and the participant was given rest for 120 s in between the trials [56]. The participant repeated the test for the non-dominant hand, and the average value from three replications was used to assess the participant's performance [57].

2.3.2. Pinch Grip Strength Test

Hand grip strength test was followed by tip (two-point) pinch, key (lateral) pinch and palmar (three-jaw chuck) pinch strength test with their dominant hand and non-dominant hand [58, 59]. The dominant hand was tested first, and the test was repeated for the non-dominant hand [58]. To undertake the test Baseline® hydraulic pinch grip dynamometer (Fabrication Enterprises Inc., United States) with a fixed grip span (2.1 cm) was used. The participants were tested with the same posture mentioned above except for the wrist between 0° and 30° dorsiflexion and between 0° and 15° of ulnar deviation. The readings of three successive trials were recorded, and the average value was used to assess the participant's performance.

2.4. Statistical Analysis

Occupational groups (weavers, block printing workers, jewelry workers) were taken as independent variables, while static muscular strength (hand and pinch grip) at the dominant and non-dominant hand were considered the dependent variables. A Shapiro-Wilk's test ($p>0.05$) [60, 61] and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the static grip strength values (hand and pinch grip) were not normally distributed for each of the individual group. Also, static grip strength was not normally distributed for overall cases.

Kruskal-Wallis H test was conducted to test the hypothesis that there was a significant difference in the grip strength values of both the hands among the groups. A Bonferroni correction was used to control for type-I error inflation due to pair-wise comparisons. Mann-Whitney U test was performed to test the other hypothesis that there was a significant difference in the static muscular strength of dominant (right) and non-dominant (left) hands within groups. Kruskal-Wallis H test and Mann-Whitney U test is a non-parametric alternative to the one-way analysis of variance (ANOVA) test and independent sample *t* test and used when ANOVA's distributional assumptions are not met [62]. All of these data were statistically analyzed using the IBM SPSS version 22. The outcomes of results from the analyses were checked for significance at 95% and 99% confidence intervals.

3. Results

The data of 120 participants were collected working in three different trades targeted for the study. Table 2 presents the correlations associated with the static muscle strength and demographic characteristics among all the workers. It also depicts overall means and standard deviations of the parameters. The results demonstrated that there were an inverse and significant correlation between age and muscle strengths in the dominant and non-dominant hand. No correlation was found between the physical parameters (weight, stature, BMI, and BSA) and muscle strength values. Whereas, the experience was negatively associated with muscle strengths in both the hands. It was evident that the highest correlations were achieved between the right and left-hand grip strength followed by the tip and key pinch strength in the dominant right hand. Whereas, the lowest correlation for pinch strength in both dominant and non-dominant hand was found between the tip and palmar strength. It was not surprising that the highest correlations were achieved between the right and left hand for each grip strength scores (e.g., right tip pinch and left tip pinch strength).

(Insert Table 2 here)

A box plot plotted for the comparative assessment shows that the muscular strength was higher among the block printing workers when compared to the other two groups (Figure 1 and 2). It could be seen that static muscle strength among the jewelry workers was more in their non-dominant hand. Overall, the interquartile range (IQR) for handgrip and tip pinch was 4.42 and 0.68 kg in both hands. The IQR for key and palmar pinch grip in the left hand was 0.91 and 0.79 kg, whereas in right hand it was 1.25 and 1.36 kg. As shown in the graph, most of the outliers were of the same cases or participants, it can be concluded that the data contain no instrumental error. However, the muscular strength of the participant can be the parameter due to which the observation was numerically distant from the rest of the data. To support the preceding results, Shapiro-Wilk's test was also conducted to test the skewness, indicated that the data was not normally distributed. So, the non-parametric approach was opted for the statistical analysis.

(Insert Figure 1 and 2 here)

The comparisons of static muscle strengths between the groups were performed using the Kruskal-Wallis H test. Mann Whitney test was used to test the difference in grip strength between both the hands. The static muscle strength values for both hands in the three groups are shown in Table 3-6. The confidence interval is constructed using bootstrap re-sampling based on function type set to percentile and variations at 1000 bootstrap subset samples. The results from the analyses translate that with 95% confidence, the true mean strength of workers is somewhere between about the upper and lower confidence limits.

From these results, it was evident that the tip, key and palmar pinch grip strength in the right and left hand of weavers and jewelry workers were significantly different. Furthermore, the handgrip and pinch strengths in dominant hand were found weaker than the non-work hand among jewelry workers. However, block printing workers showed no significant difference in strength values for both the hands. The results from the Kruskal-Wallis test shows that the all the groups were statistically different ($p<0.05$) in all the strength measurement scores for the right hand. Key pinch and palmar pinch strengths were significantly different ($p<0.01$) among each group for the left hand. Though the summary illustrates no specific details that may conclude about the difference in static muscle strength for non-dominant hand among each group of workers.

(Insert Table 3 to 6 here)

In the present analyses, a Bonferroni adjustment was used to control for the familywise type-I error rate in determining whether Kruskal-Wallis H test was significant (Table 7). Despite the overall significance in the grip strength of right-hand, only jewelry and block printing workers were significant beyond the 0.05 level, two-tailed test after using a Bonferroni correction. Also, for right-hand tip pinch strength, jewelry workers were significant from block printing workers (*at* $p<0.01$). Although the key and palmar pinch strengths in the left-hand between weavers and block printing workers were statistically significant *(at* $p<0.01$*)*, no significance was observed in the right-hand. The difference in palmar pinch strength between the weavers and jewelry workers were found significant in both the hands. Furthermore, key pinch strength in only left-hand showed the asymptotic significant difference between weavers and jewelry workers *(at* $p<0.05$*)*. Therefore, it could be inferred from the results that jewelry workers had the weakest work hand when compared with other groups.

(Insert Table 7 here)

4. Discussion

This study presents the evidence that static muscle strength may be influenced due to repetitive use of hand tools for a prolonged period, albeit to a moderate degree. This is the first cross-sectional comparative study of its kind to evaluate the static muscle strength among the handicraft operatives of different vocations in India.

Previous studies [59, 63] have established that there are an inverse and significant correlation between age and muscle strengths. Results from our study were also in line with them showing a negative association between age and all measured strengths in dominant and non-dominant hand. Also, the experience was significantly and inversely associated with all grip and pinch strength values. Thus it signifies that as the experience and age grow, the muscular strength among the worker's also tends to decrease. A few studies [64, 65] have reported a positive correlation between grip strength, weight, and stature in healthy participants. On the contrary, Robertson et al. (1996) recognized that a positive relationship between grip strength, and anthropometry may not occur in individuals with hand dysfunction [66]. Based on our results, no significant correlation could be obtained between the grip strength values, weight, and stature among the handicraft workers. Perhaps a larger sample size may infer accurate information about the association.

The experimental analysis reveals that the exposure to jewelry work was associated with an apparent decrease in pinch strength measures when compared to other hand-intensive jobs. This is further exemplified in a reciprocal comparison to the strength of the contralateral limb. The overall interpretation of the results from strength comparisons suggests that the jewelry workers had consistently weaker hand and pinch grip strength parameters than the other groups. An apparent decrease in muscle strength that jewelry workers suffered could be due to work exposure.

In every group aside from jewelry, the non-work hand was either weaker or equivalent to the work hand, which makes sense, due to handedness and from natural hypertrophy due to the physical nature of work. However, with the jewelry workers, the work hand was weaker than the non-work hand in each of these measurements, perhaps even implying an increased risk of injury due to the type of daily work. In fact, the grip strength of their non-work hand was more or less similar to that of other groups. Perhaps, the reason could be that their dominant right hand was exposed to hand-arm vibration during pearl hole drilling. The difference in grip strength in work and non-work hand indicate that the exposure to hand tools for a prolonged period is highly associated with a reduction in muscle strength. Several investigators have suggested that the effect of hand vibrations are directly associated with a loss of static grip strength [48, 67-69].

Many researchers in the past have misunderstood the statistical and clinical outcomes, and mistakenly relate statistical significance to clinical relevance [70]. Measures including clinical significance, effect sizes, confidence intervals, and magnitude-based inferences could be used to determine clinical relevance. Minimal clinically important differences (MCID) was used to evaluate the clinical relevance of the results obtained during the present study. A mean difference between the different groups that are higher than the MCID of 2 should be clinically relevant [71]. MCID was calculated by multiplying the pooled baseline standard deviation scores by 0.2 [72]. It was quite surprising that even though the difference in static muscle strength values in right and left-hand was statistically significant, none of them were found clinically significant.

Some quantitative studies have demonstrated that the major health-related problems associated with carpet weavers are MSDs in lower back, shoulders, elbow, and wrist regions due to high force exertion on limbs during weaving [73, 10, 29]. The risk of CTS and upper extremity MSDs (shoulders, elbow and hand/wrist disorders) is due to repetitive movement of hand and wrists muscles during weaving [74]. The findings of the previous literature examined that the upper extremity MSDs is associated with the significant drop in grip strength [75-77]. It also depends on the type of work [78]. Based on the results from the present study, it could be seen that the pinch grip strength of the non-dominant (left) hand among weavers was lowest among other groups. The drop in pinch grip strength could be due to repetitive use of the distal phalanx in digits during knotting which involves both hands. The long cycle repetitive pinching movements (knotting) and forced cylindrical grasping (weaving knife) could be the cause of variation in the static muscle strength.

Unlike the other groups, block printing workers showed no noticeable difference in the static muscle strength between both the hands. They have also shown a relatively higher muscle strength than the other two group of workers, which may partly be attributed lower level of occupational stress during block printing. The inferences drawn from the present results could be supported by the study showing that the complaints of work-related MSDs among hand block printing workers were lower back pain, shoulders pain, upper back pain and knee pain due to the improper ergonomically designed workstation. Not much discomfort was reported in wrist/hand regions [34].

Liu and Chu (2006) reported that the physical demand of the occupations is directly associated with the grip strength of the workers [44]. Pearl bead drilling is challenging and extremely labor intensive as compared to other imitation jewelry tasks. The physical examination in this research showed that the jewelry workers suffered a significant loss in the tip, pinch and palmar pinch grip strength in their work hand as compared with the non-work hand. The reason seems to be due to high force exertion on digits and prolonged awkward working posture exerting excessive muscle pressure during drilling holes. Perhaps, the worker holds (pinch grasp) the pearl against the bit throughout their daily work. No noticeable difference was observed in the left hand with the other groups since the process of drilling requires the minimum use of the left hand.

Further longitudinal work is needed to explore the ergonomic designs of work system and hand tool interventions that are adjustable in terms of the anthropometric dimensions of the jewelry workers. It is advisable to carry out studies to unravel the specific fixtures that may reduce the vibration magnitudes and sound pressure level within the acceptable limits. Perhaps, it leads to effective sustainability and the improvement in the quality of work life among the workers.

Highly repetitive activities in the handicraft work is another ergonomic risk factor which may lead to the risk of upper limb MSDs [1]. Silverstein et al. (1987) also point out that CTS was strongly associated with high repetitive jobs and the odds ratio for the high repetitive jobs was more than 15 *(at $p<0.001$)* when compared to low repetitive jobs [79]. A large number of clinical investigations have reported that the reduction in grip strength is related to the high repetitiveness of the upper limbs [2, 3, 29, 32]. Apart from the loss of grip strength, repetition plays a vital role in the development of physiological stress among the workers [80]. Singh et al. (2017, 2018) carried out the physiological assessment of the workload by recording the heart rate and blood pressure of the carpet washer-men and weavers before and after the continuous work activity [16, 29]. The results revealed that there was a tendency to rise in blood pressure and heart rate after continuous work activity during carpet washing. However, no significant effect was reported in blood pressure during the weaving, though an increase in heart rate was observed.

This research evaluates the muscle strength involved in different hand intensive handicrafts work. As the grip data were recorded in a similar way, unfatigued prior to work shift, it can be assumed that the loss of muscle strength among the women workers not only prevail during work but also persists during the household activities and rest periods. To the best of author's knowledge, the comparative assessment of static muscle strength among the handicraft operatives in India has never been studied, and the present work is the first one in which this approach is taken. This can lead to the need for attention and investigation of the current workstation. Given the cross-sectional design of this study, it must be borne in mind that the collection of grip strength data was conducted on a small group of women workers, these findings must be interpreted with caution. Finally, the present study is a field-based study without clinical examination for the same environmental settings, which could be its limitation. Future directions include repeatability assessment over multiple work shifts. Further longitudinal work is needed to explore the ergonomic designs of work system.

5. Conclusion

This is one of the first attempts that quantitatively evaluated the level of grip strength that female handicraft workers acquire due to the occupational stress. In conclusion, the findings of the present study provide evidence that the jewelry workers suffered a relatively higher loss in grip strength in their dominant hand as compared to weavers and block printing workers, implying an increased risk of injury associated with jewelry work. This may be due to poorly designed hand tools and workstation they are exposed to in their professional life. Although the majority of tasks performed by the handicraft operatives were relatively similar (repetitive hand/finger movement, etc.), their physical workload (frequency and duration of exposure) was different which may be attributed to the difference in static muscle strength. The occupational problems cannot be eliminated entirely, but, they can be minimized with the implementation of some ergonomic work system interventions and guidelines, which eventually enhance the health conditions and productivity of the workers. This study was a preliminary investigation of female handicrafts operatives from a sample group suggesting that in future studies, muscular strength factor must be taken into account while assessing the level of musculoskeletal fitness among the workers.

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Figure Legends

Figure 1. Box plot showing hand grip strength values among the three groups for right and left hand.

Note: Error bars (whiskers) denote the variability outside the upper and lower quartiles.

Figure 2. Box plot showing tip, key and palmar pinch grip strength values among the three groups for right and left hand.

Note: Error bars (whiskers) denote the variability outside the upper and lower quartiles. Circle denotes the data points that are within 1.5 times the interquartile range (IQR) above the upper quartile located but outside the whiskers. Star indicates the outliers that are larger than 1.5 times the IQR. Most of the outliers were of the same cases or participants. Here, 116 shows the participant's serial number/case. The full colour version of this figure is available online.

Table 1. Demographic characteristics of the group of workers.

Variable	Median (Interquartile Range)				Kruskal Wallis *p* value
	Overall (*N* = 120)	Weaver (*n* = 45)	Block Printer (*n* = 45)	Jewelry Worker (*n* = 30)	
Age of participant (years)	30.0 (24.0-35.0)	26.0 (22.0-35.0)	32.0 (24.0-35.0)	32.0 (26.0-35.0)	0.107
Weight of participant (Kg)	46.35 (41.80-53.68)	44.0 (41.7-51.8)	47.30 (41.4-52.6)	47.20 (41.6-55.5)	0.328
Stature of participant (m)	1.54 (1.50-1.58)	1.53 (1.49-1.57)	1.54 (1.50-1.58)	1.54 (1.52-1.59)	0.158
BMI	19.16 (17.26-22.79)	18.92 (17.51-22.68)	19.77 (16.88-22.22)	19.42 (17.59-23.52)	0.766
BSA (m^2)	1.42 (1.32-1.50)	1.36 (1.32-1.46)	1.43 (1.33-1.49)	1.45 (1.34-1.55)	0.164
Experience (years)	10.50 (6.0-16.0)	10.0 (4.5-15.0)	15.0 (8.0-20.0)	11.0 (5.75-17.0)	0.135

** (p<0.05)*

Note: BMI = Body mass index; BSA = Body surface area; Medians and Interquartile Ranges (IQR, 25th-75th percentile) for physical parameters (non-normally distributed).

Table 2. Pearson correlations, means and standard deviations associated with static muscle strength and demographic characteristics among all the workers.

Parameter	Hand Grip Strength-L	Hand Grip Strength-R	Tip Pinch-L	Tip Pinch-R	Key Pinch-L	Key Pinch-R	Palmar Pinch-L	Palmar Pinch-R	Age	Weight	Stature	BSA	BMI	Experience	Mean	SD
Hand Grip Strength- L	1														30.40	2.77
Hand Grip Strength-R	0.890**	1													30.77	2.73
Tip Pinch-L	0.146	0.069	1												2.44	0.67
Tip Pinch-R	0.126	0.132	0.720**	1											2.53	0.68
Key Pinch-L	0.095	0.037	0.634**	0.541**	1										2.96	0.68
Key Pinch-R	0.166	0.187*	0.643**	0.805**	0.683**	1									2.98	0.70
Palmar Pinch-L	0.101	0.055	0.426**	0.404**	0.485**	0.485**	1								4.76	0.65
Palmar Pinch-R	0.246*	0.321**	0.456**	0.606**	0.499**	0.737**	0.533**	1							4.76	0.79
Age	-0.386**	-0.431**	-0.392**	-0.280*	-0.377**	-0.290*	-0.457**	-0.428**	1						29.81	7.36
Weight	0.056	-0.055	0.098	-0.065	0.056	0.101	-0.105	-0.101	0.354**	1					47.57	8.30
Stature	0.109	0.178	-0.057	0.032	0.059	0.059	0.188	0.050	0.156	0.237*	1				1.54	0.06
BSA	0.069	0.032	0.084	-0.060	0.058	0.047	-0.087	-0.096	0.361**	0.974**	0.446**	1			1.42	0.13
BMI	0.023	-0.043	0.087	-0.051	0.048	0.083	-0.108	-0.096	0.277**	0.881**	-0.244*	0.755**	1		20.13	3.53
Experience	-0.345**	-0.415**	-0.259*	-0.231*	-0.337**	-0.317**	-0.418**	-0.405**	0.686**	-0.028	0.192*	0.018	-0.102	1	11.89	7.14

*** Correlation is significant at the 0.01 level (2-tailed).*

** Correlation is significant at the 0.05 level (2-tailed).*

Note. L = Left Hand; R = Right Hand; BSA = Body surface area; BMI = Body mass index.

Table 3. Hand grip strength (kg) among the handicraft workers group.

Participant	Right Hand		Left Hand		Mann Whitney *p* value
	Mean	95% CI [LCL, UCL]	Mean	95% CI [LCL, UCL]	
Weavers	30.5	29.8, 31.2	29.8	29.1, 30.6	0.193
Block Printing Workers	31.6	30.7, 32.5	30.9	30.0. 31.8	0.290
Jewelry Workers	29.9	29.0, 30.9	30.5	29.5, 31.5	0.374
Kruskal Wallis *p* value	0.046*		0.217		

** (p<0.05)*
*** (p<0.01)*
Note. CI = Confidence Interval; LCL = Lower confidence limit; UCL = Upper confidence limit.

Table 4. Tip pinch grip strength (kg) among the handicraft workers group.

Participant	Right Hand		Left Hand		Mann Whitney *p* value
	Mean	95% CI [LCL, UCL]	Mean	95% CI [LCL, UCL]	
Weavers	2.5	2.3, 2.7	2.3	2.1, 2.5	0.037*
Block Printing Workers	2.8	2.5, 3.0	2.5	2.3, 2.7	0.086†
Jewelry Workers	2.2	2.0, 2.5	2.5	2.3, 2.7	0.027*
Kruskal Wallis *p* value	0.003**		0.092†		

** (p<0.05)*
*** (p<0.01)*
† (slight but not significant)
Note. CI = Confidence Interval; LCL = Lower confidence limit; UCL = Upper confidence limit.

Table 5. Key pinch grip strength (kg) among the handicraft workers group.

Participant	Right Hand		Left Hand		Mann Whitney *p* value
	Mean	95% CI [LCL, UCL]	Mean	95% CI [LCL, UCL]	
Weavers	2.9	2.7, 3.1	2.7	2.5, 2.9	0.044*
Block Printing Workers	3.2	3.0, 3.5	3.1	3.0, 3.3	0.627
Jewelry Workers	2.7	2.5, 2.9	3.1	2.9, 3.3	0.005**
Kruskal Wallis *p* value	0.001**		<0.001**		

** (p<0.05)*
*** (p<0.01)*
Note. CI = Confidence Interval; LCL = Lower confidence limit; UCL = Upper confidence limit.

Table 6. Palmar pinch grip strength (kg) among the handicraft workers group.

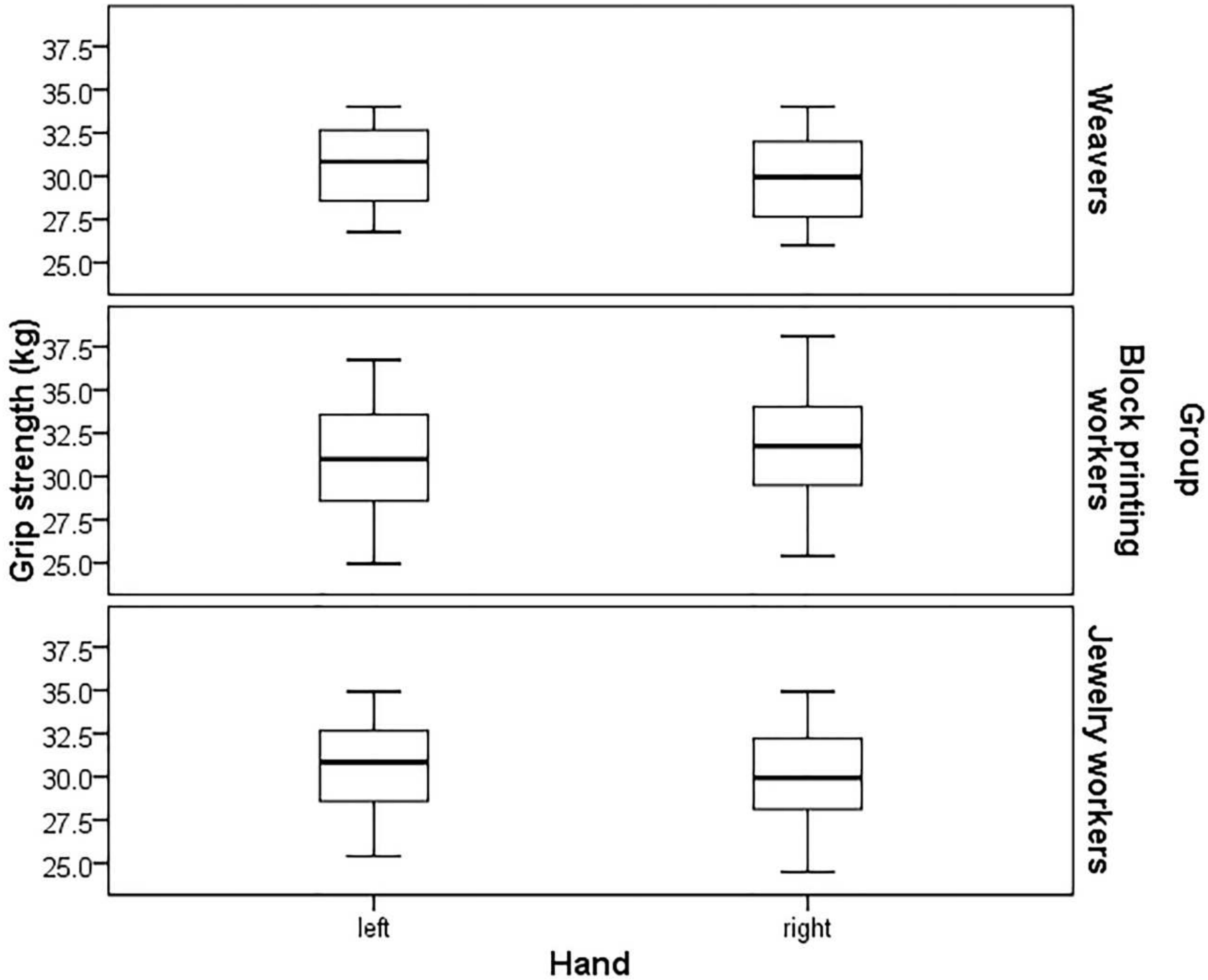
Participant	Right Hand		Left Hand		Mann Whitney *p* value
	Mean	95% CI [LCL, UCL]	Mean	95% CI [LCL, UCL]	
Weavers	4.8	4.6, 5.0	4.5	4.3, 4.7	0.028*
Block Printing Workers	5.1	4.9, 5.4	4.9	4.8, 5.1	0.104
Jewelry Workers	4.2	3.9, 4.4	5.0	4.8, 5.2	<0.001**
Kruskal Wallis *p* value		<0.001**		<0.001**	

** (p<0.05)*
*** (p<0.01)*
Note. CI = Confidence Interval; LCL = Lower confidence limit; UCL = Upper confidence limit.

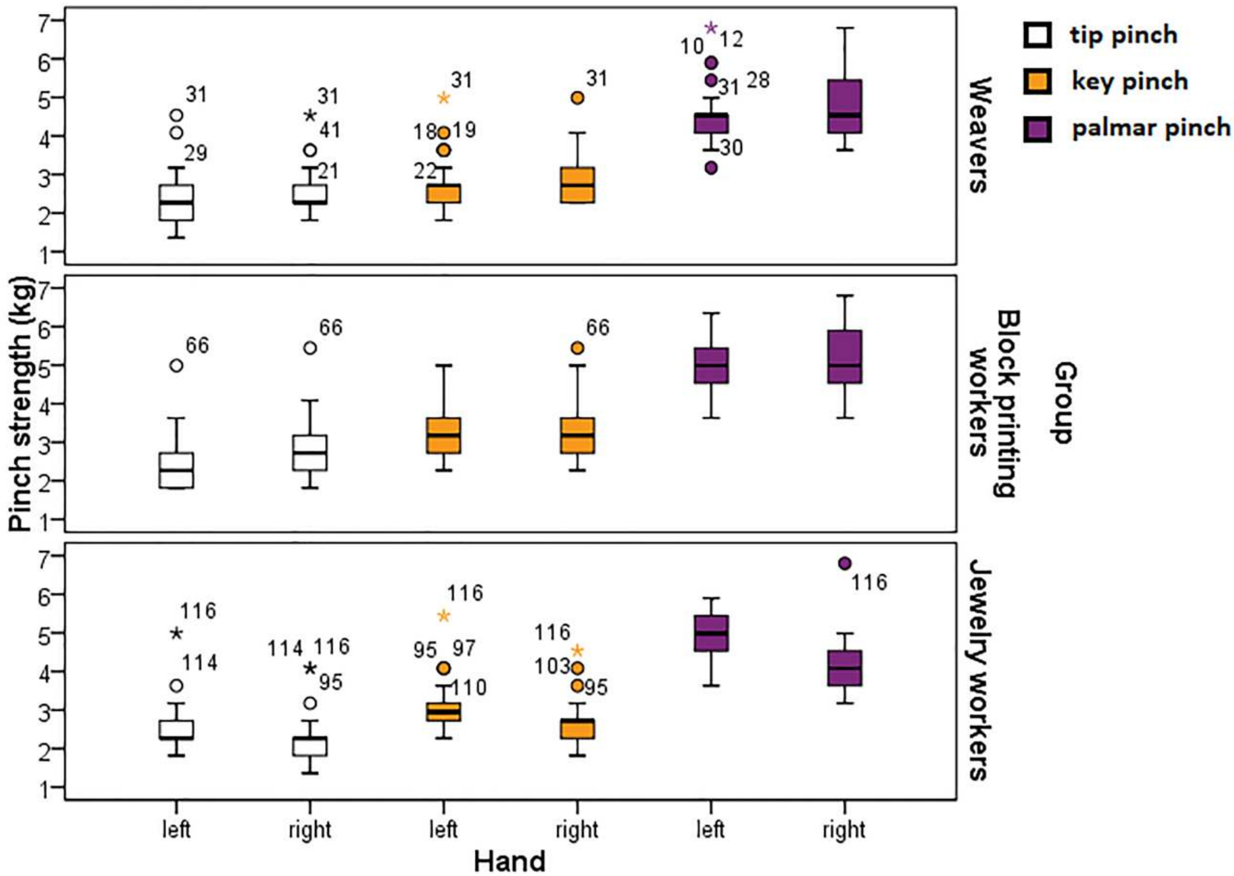
Table 7. Kruskal-Wallis H test post hoc multiple comparisons (Bonferroni analysis) to explore all possible pair-wise comparisons between the groups.

Group (I)	Group (J)	significance at 95% and 99% confidence interval			
	Grip Strength at Right Hand	Hand Grip	Tip Pinch Grip	Key Pinch Grip	Palmar Pinch Grip
1	2			†	†
	3				**
2	3	*	**	**	**
	Grip Strength at Left Hand				
1	2			**	**
	3			*	**
2	3				

** (p<0.05)*
*** (p<0.01)*
† (slight but not significant)
Note: Group 1 = Carpet weavers; Group 2 = Block printing workers; Group 3 = Imitation jewelry workers. Blank pair imply no significant difference between the groups after using a Bonferroni correction.


Grip strength (kg)
37.5
35.0
32.5
30.0
27.5
25.0
Weavers
Block printing workers
Jewelry workers
Group
left
right
Hand

38

39 

tip pinch
key pinch
palmar pinch
Weavers
Block printing workers
Jewelry workers
Group
Pinch strength (kg)
Hand
left
right
left
right
left
right