Isometric handgrip strength of agricultural workers from northeast region of India

Thaneswer Patel[1], J Sanjog[2], Sougata Karmakar[2*]

(1. *Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli – 791 109, Arunachal Pradesh, India;*

2. Department of Design, Indian Institute of Technology (IIT) Guwahati, Guwahati - 781 039, Assam, India)

Abstract: Handgrip strength is considered as one of the most important factors for performing various agricultural tasks related to torqueing, lifting, pulling, pushing, etc. Hand tools and equipment which are designed based on anthropometric/strength data of a particular population, may not be suitable for other targeted user groups. As a result work related musculoskeletal disorders at upper extremity may occur very often. Lack of strength data of Assamese population (people of Assam, a state in northeast India) motivated present authors to conduct a survey on isometric handgrip strength data, initiated with 'Kamrup' district of Assam. Isometric strength data were measured with a representative sample of 200 agricultural workers (130 male and 70 female, aged 17-62 yr) from the aforesaid district of the state. Maximal isometric handgrip strength was determined using a handheld handgrip dynamometer with standard testing position, protocol and instructions. Descriptive statistics such as mean, standard deviation (SD), percentiles etc. were summarized. Results of student's t-tests showed significant differences ($p<0.05$) for handgrip strength (in kg) between male and female workers (30.11 ± 7.06 vs. 19.75 ± 5.38 for right hand and 26.59 ± 6.84 vs. 15.96 ± 5.74 for left hand). It was observed that with increasing age, there was significant declining in handgrip strength across age groups (<30 yr, 30-40 yr and >40 yr). Further, handgrip strength of female was found significantly lower (in general 2/3rd) than their male counter parts. This confirms the requirement of gender specific tools and equipment design. Collected data is expected to bridge the gap of unavailability of isometric handgrip strength data of Assamese population and would help in agricultural tools/equipment design suitable for the said population.

Keywords:handgrip strength, muscular strength, anthropometry, percentile, maximal voluntary contraction (MVC), India

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1 Introduction

Human muscular strength is still most extensively used and, of fundamental importance for operating various tools and equipment in agricultural activities. The efficiency of operator-hand tool system depends on the human operator, the tool, and the task. The understanding of relationship between the capabilities of the worker and the force requirement to operate hand tool is essential for improving overall system performance and comfort, safety and productivity of human workers. Therefore, the force/torque exertion capabilities of humans with various hand tools should be known. The measurement of muscular strength is performed under static and dynamic muscle contractions. Static muscular force measurement is also known as isometric in nature where movement of all involved joints are restricted during muscle contraction. Strength measures related to legs, back, arms and shoulders are mostly reported by researchers (Petersen and Schack, 1974; Mital and Ayoub, 1980; Pitetti et al., 1992; Mehta et al., 2007). Varieties of portable equipment are available for measurement of

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***Corresponding author:Karmakar, S.,** Department of Design, Indian Institute of Technology (IIT) Guwahati, Guwahati - 781 039, Assam, India. Phone: + 91-361-2582464; Fax: +91-361-2690762; E-mail: karmakar.sougata@gmail.com.

handgrip force but handgrip dynamometers are most widely used and accepted by various researchers (Smith and Benge, 1985; Robertson et al., 1993). Isometric force measurement is more popular due to its relative simplicity, short testing time, low cost of equipment and test-re-test reliability (Niebuhr et al., 1994; Hamilton et al., 1994).The human strength capability under specified conditions is of great practical importance in ergonomics/human factor for design of workplace, tools, equipment etc.

Human factors engineers/ergonomists have to rely on anthropometric and muscular strength data for producing ergonomically designed product, otherwise the acceptability and product output may be not be satisfactory (Patel et al., 2013). Nowadays, tools and equipment designers and manufacturers tend to have focused on the importance of human factors in order to improve comfort, safety and protect the health of workers with user centric design approach considering end-users at the early stages of the design process. The acceptability of tools and equipment among workers depends upon how design and force requirement matches between job demands and capacity of workers who perform the work. Therefore, database of static strength capabilities and limitations of targeted workers must be established to optimize performance. The maximum force that a muscle or muscle group can generate is greatest during an isometric contraction, provided it is performed at an optimal joint angle (Patel et al., 2014). For ergonomically design of tools and equipment, knowledge of human strength capabilities and limitations of targeted users are crucial factors.

Age-related changes in handgrip strength have been reported by various researchers (Mathiowetz et al., 1985; Carmelli and Reed, 2000). The handgrip performance and physical activity in older persons is consistently lower than that of their younger counterparts for both male and female. Handgrip strength test for maximal voluntary contraction (MVC) depends on a number factors such as measurement technique, posture, gender, age, types of occupational activity, wrist position, forearm position and grip spans (Sartorio et al., 2002; Visnapuu and Jurimae, 2007). The optimal range of grip span varies between the genders. However, some of researchers reported optimal grip span in the range of 50-65 mm for male, and about 5 mm less for female (Imrhan, 1999). In general, the average handgrip strength of male agricultural workers of India falls in the range 300-450 N for dominant hand and 250-400 N for opposite hand while for female, 55-70 per cent of those values respectively. In order to avoid musculoskeletal disorders of the upper extremities in agricultural workers due to overloading of muscles in operation of tools and equipment, static musculoskeletal loads need to be determined.

The agricultural production systems in the hilly region of northeast region of India differ from the plough cultivation in the plain lands. In hilly region, animate power (human and animal) is the main source for performing various agricultural operations. In this region, 80% of the farmers land holdings are generally small (<1.44ha) and marginal (<0.40 ha) category, where mechanization of agriculture and adoption of modern technology is not feasible. This is primarily because hilly terrain constitutes nearly two-thirds of the region's geographical area, and large sized holdings are not feasible. Therefore, in the absence of adequate modern technology, manual powered small tools and implements are predominantly used for agricultural activities. Biomechanical database are fundamental determinants for ergonomically design of tools and equipment. From literature review it has been observed that very limited muscular strength database has been generated in northeast region of India for tools and equipment design (Dewangan et al. 2010; Agrawal et al. 2009).

Lack of strength data of Assamese population (people of Assam, a state in northeast India) motivated present authors to conduct a field survey on handgrip strength (maximal voluntary contraction) for both male and

female agricultural workers from Assam. Further, an effort was made to analyse collected data for different age groups (<30 yr, 30-40 yr and >40yr) in order to understand age-related variations in grip strengths.

2 Methods

2.1 Participants

A representative sample of 200 participants is recommended for good correlation (r>0.8) with 90% and 95% power and significance level, respectively (Chandrasekaran et al., 2010). Therefore, in the present study, a convenience sample of 200 agricultural workers (130 male and 70 female) from Kamrup district Assam, ranging in age from 17 to 62 yr, selected for the study. Male subjects had an average (± standard deviation) age: 37.25±11.74 yr, stature: 162.75±4.59 cm and body weight: 55.22±7.00 kg. Female subjects had an average age: 34.30±10.63 yr, stature: 153.10±4.83cm and body weight: 48.49±7.72 kg. The subjects were informed about this study and those participants who agreed to their participation were selected. Before commencing the test,consent form and self-responded short questionnaire related to previous history of neurological disorder, inflammatory joint diseases, injury to upper limb etc. which would significantly affect hand strength were collected for inclusion/exclusion criteria. Hand dominance was determined by knowing the preferred hand used for eating and doing various agricultural activities. In this study all the participants were right handed therefore right hand was considered as dominant hand and left hand as opposite hand.

2.2 Instrument

Anthropometric body dimensions were measured for each participant. The stature was measured with the help of portable anthropometric kits and measurement was reported to the nearest 0.1 cm. Body weight was measured by mechanical bathroom weighing scale to the nearest 0.1 kg. Body Mass Index (BMI) was calculated from a participant's weight and height (body weight in kg/height in m^2). Handgrip strength measurement was taken with the Jamar dynamometer (Sammons Preston Inc., Boling-brook, IL, USA). Handheld dynamometry is most valid and reliable for measurement of maximal isometric muscular strength (Sullivan et al., 1988; Bohannon, 1986). These dynamometers consisted of five handle positions and a dial representing force value. The strength reading can be viewed as kilograms or pounds maximum of 90 kg or 200 lb to the nearest 1 kg or 2.5 lb. The highest reading on the dial was noted from peak-hold needle which was reset for next trail/reading.

2.3 Measurement

Handgrip strength test was performed in standing position for both dominant and opposite hands. Each subject stands in the erect position with his/her arms hanging downwards, trunk and wrist in neutral positions to provide maximum handgrip force. For each hand three replications were recorded. A rest pause of about 3-5 min in between two trials was given to the individual subject in order to avoid fatigue in muscles. Each subject performed grip tests on both the hands at the same day. For standardisation, the dynamometer was set at the second handle position (of the five positions available) and adjusted if required for comfortable of holding. The upper and lower parts of dynamometer handle rested on first metacarpal (heel of palm) and middle of four fingers respectively, as shown in Figure 1. Each participant was instructed to hold the handle of the dynamometer and squeeze with the right hand (dominant) and then left hand (opposite) for maximum isometric effort as hard as they can for a period of 3-5 s without movement of other body parts. As the subjects began to squeeze, verbal encouragements (little more, you can do it more, and finally relax) were given to record a maximum effort. With the same instructions second and third trial were recorded for each hand in the alternating pattern. The results were recorded as kilograms. All the values of three trails were noted and only peak value of three trails of each strength measurement i.e. right and left hands were used for analysis.

Figure 1 Handgrip strength measurement technique

2.4 Statistical analysis

All data analyses were carried out using commercially available statistical software, IBM SPSS Statistics for Windows (Version 22; SPSS Inc., Chicago, IL, USA). Normality of data were evaluated by Shapiro-Wilks test (p>0.05), and by visual inspection (Q-Q plot). The findings of the above tests results indicated that none of the data violated assumptions of normality. The comparisons of handgrip strength data between the male and female workers were presented as mean, minimum, maximum, SD, standard error of the mean, coefficient of variation, percentiles etc. All data were presented as mean values ± standard deviation. The assumption of homogeneity of variances between groups was tested with Levene's test for selecting suitable t-test. Student's 2-sample independent t-test was performed to determine statistical significance of differences between groups. The levels of significance i.e. alpha at p<0.01 and p<0.05 were considered statistically significant.

3 Results

The age of the male and female participants ranged from 17 to 62 yr and 19 to 56 yr, respectively. The total percentage of participants at three age groups viz., less than 30, 30-40 and more than 40 yr were 34%, 29% and 37% for male, while 39%, 29% and 33% for female respectively. Descriptive statistics of participants is present in Table 1. The t-test results showed significant differences between male and female height and body weight for various age groups (p< 0.05). However, there was no statistically significant difference in the mean age except in more than 40 years age group. Body Mass Index (BMI) was found statistically insignificant between male and female groups except for age more than 40 years (p<0.05).

Table 1 Basic summary of the physical characteristics of the group of test participants

Anthropometric measurements	<30 yr Mean (SD)	30-40 yr Mean (SD)	>40 yr Mean (SD)	Whole group Mean (SD)
Male	n = 44	n = 38	n = 48	n = 130
Age, yr	24.14 (3.41)	36.13(2.92)	50.15(5.42)	37.25(11.74)
Stature, cm	163.47(4.10)	162.83(5.14)	162.04(4.56)	162.75(4.59)
Body mass, kg	53.55(5.20)	55.53(6.15)	56.50(8.70)	55.22(7.00)
BMI	20.03 (1.75)	20.93(2.03)	21.52(3.23)	20.84(2.53)
Female	n = 27	n = 20	n = 23	n = 70
Age, yr	23.04(2.59)	34.95(3.33)	46.96*(3.67)	34.30 (10.63)
Stature, cm	152.96*(2.97)	154.70*(4.26)	151.88*(6.56)	153.10*(4.83)
Body mass, kg	48.22*(4.84)	51.45*(8.37)	46.22*(9.22)	48.49*(7.72)
BMI	20.66(2.47)	21.45(3.07)	19.91*(2.99)	20.64(2.85)

Note: n = sample size, SD = standard deviation; * = mean difference between male and female workers of a group significant at$p<0.05$.

The male and female agricultural workers mean, minimum, maximum, SD, COV(%), SEM, 95% confidence lower and upper limits, 5th and 95th percentile values are tabulated in Table2. The handgrip measurements mean strength for right (dominant) and left (opposite) hands were 295.28±69.23 N and 260.76±67.08 N for males whereas, 193.68±52.76 N and 156.51±56.29 N for females, respectively. The coefficient of variation

(the ratio of standard deviation to the mean) of grip strength for dominant hand and opposite hand was found to be higher for female participants compared to male participants. Significant higher variations were found while differences in the range of age of subjects were higher.

Table 2 Comparisions of dominant hand and opositehand strength of male and female agricultural workers (n=200)

Subject	Measure	Dominant hand	Opposite hand
Male	Mean	295.28	260.76
	Min.	129.45	114.74
	Max.	492.29	441.30
	St. deviation	69.23	67.08
	COV (%)	23.44	25.74
	SEM	6.08	5.88
	Lower limit#	283.31	249.19
	Upper limit#	307.24	272.33
	5th percentile	181.42	150.34
	95th percentile	409.13	371.08
Female	Mean	193.68	156.51
	Min.	92.18	61.78
	Max.	334.41	288.32
	St. deviation	52.76	56.29
	COV (%)	27.25	35.97
	SEM	6.28	6.77
	Lower limit#	181.42	143.28
	Upper limit#	205.94	169.75
	5th percentile	106.89	63.94
	95th percentile	280.57	249.09

Note: Measurement unit = newton (N); Min. = minimum; Max. = maximum; SEM = standard error of the mean; COV = coefficient of variation; # = 95% confidence interval for the mean

Handgrip strength depends upon various factors such as gender, age, physical fitness, hand preference of the individual etc. Various researchers reported age related decline of muscular strength (Lindle et al., 1997; Beckett et al., 1996; Pieterse et al., 2002). Some of the researchers found positive correlation of grip strength with height and weight (Newman et al., 1984). The handgrip strength for three age groups viz., less than 30 years, 30-40 yr and more than 40 yr of present research were plotted with the help of a bar graph as shown in Figure 2. It was observed that there were variations of grip strength across age groups and gender difference. Handgrip strength was found to be decreased with age in both hands for male and female. Irrespective of age and sex variation, handgrip strength of the dominant hand was found higher than the opposite hand. Further, males are stronger than females and produced significantly higher grip strength in all the age groups (age groups of <30 years, 30-40 yr and >40 yr for male and female, dominant and opposite handgrip strength were 32.43 kg and 28.01 kg; 30.38 kg and 27.34kg; 27.76 kg, and 24.69 kg for male while 20.8 kg and 18.1 kg; 19.29 kg and 15.74 kg; 18.93 kg and 13.64 kg for female respectively at $p<0.05$). The findings of the above results indicated that grip strength variation between genders were not the same for all age groups. For the youngest group of <30 yr, the males exhibited 9.91 kg and 11.63 kg more strength; for the middle group of 30-40 yr old, the males showed 11.09 kg and 11.6 kg more strength, and for the oldest group of more than 40 years, the males were found8.83 kg and 11.05 kg more strength for dominant and opposite hands respectively.

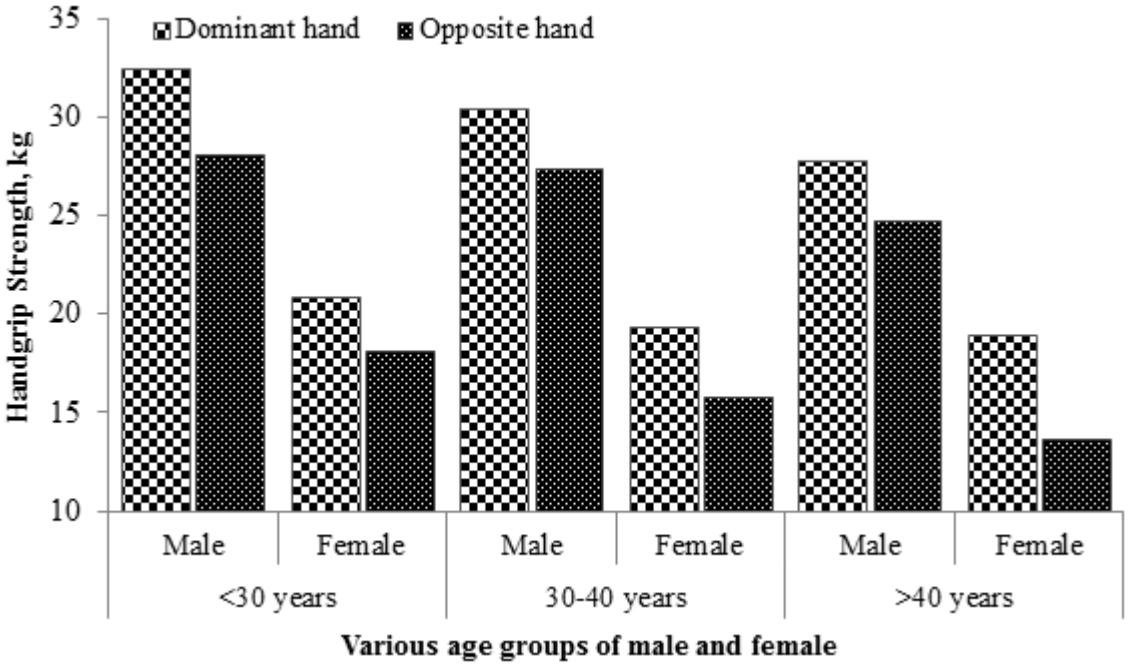

Figure2 Strength for dominant and opposite hands for male and female workers of different age groups

The t-test was performed to determine the differences between mean values of handgrip strength of agricultural workers of Assam and the other regions of India viz., Jammu and Kashmir (J&K), Madhya Pradesh (MP), Maharashtra (MH), Orissa (OR) and Tamil Nadu (TN) states. The results indicated that the data of Assamese population differ significantly ($p< 0.01$, $p<0.05$) in all the cases except handgrip strength data for opposite hand (t-value = -1.46) of female agricultural workers from Maharashtra state as shown in Table 3. These significant differences in strength capability of Assamese agricultural workers (either male or female) with other states of India, clearly indicate that the tools and equipment design should be region specific.

Table 3 Comparison of mean (SD) handgrip strength data of agricultural workers of present study (i.e. Assam state) with data from other states of India

State	Dominant hand		Opposite hand		Dominant hand		Opposite hand	
	Male Mean(SD)	Female Mean(SD)	Male Mean(SD)	Female Mean(SD)	Male (t-test)	Female (t-test)	Male (t-test)	Female (t-test)
AS[#]	295(69)	194(53)	261(67)	157(56)	-	-	-	-
J&K[$]	313(52)	140(33)	294(51)	120(29)	-2.77[**]	8.03[**]	-5.23[**]	5.30[**]
MP[$]	404(110)	242(88)	377(110)	211(89)	-15.22[**]	-6.43[**]	-16.54[**]	-6.92[**]
MH[$]	326(66)	180(44)	313(65)	167(42)	-5.08[**]	2.15[*]	-8.67[**]	-1.46[NS]
OR[$]	336(82)	225(69)	326(79)	207(57)	-4.71[**]	-3.58[**]	-7.71[**]	-6.04[**]
TN[$]	412(87)	275(70)	388(106)	274(73)	-16.74[**]	-11.95[**]	-17.49[**]	-16.37[**]

Note: measurement unit = newton (N); [#] = present study i.e. Assam state; [$] = Gite et al., 2009; [**] = statistically significant ($p<0.01$); [*] = statistically significant ($p<0.05$); NS = statistically not significant

4Discussion

Handgrip strength is one of the most important possible predictor of overall body strength. The designers and manufactures could improve the design, functionality, and ergonomics of manually operated tools and equipment to increase workers' satisfaction and productivity with use appropriate database of targeted

population. However, due to lack of fundamental database many tools and equipment manufacturer do not consider variability in their target user population and simply design for the average population. Many researchers pointed out that grip strength is observed maximum during early adult life and declines progressively after the second or third decade of life (Burke et al., 1953; Kellor et al., 1971). In present research significant reduction of isometric handgrip strength was also observed for both hands across ascending age groups under study.

Strength data comparison (%difference) between mean values of male and female agricultural workers is shown in Table 4. It is observed from the Table 4 that %difference between male and female varies from 32% to 37% for dominant hand and 36% to 45% for opposite hand. The parentage variation in handgrip strength for male and female dominant and opposite hand were found lower in the younger age group i.e. <30 yr and higher for the older age group i.e. >40 yr. The independent sample t-test results showed that there was significant difference in handgrip strength for both hands at significance level 5% between male and female across various age groups. Further, from the combined handgrip strength data (pooled data) of male and female, across age groups showed that capability of dominant hand was significantly higher (p<0.05) than opposite hand. The difference in strength between male and female participants is due to greater muscle mass in male (Patel et al. 2014). Evidence has shown that male muscular strength is always more than their female counterparts (Agrawal et al., 2009; Gite et al., 2009; Tiwari et al., 2010). Further, muscular grip force of the dominant hand is always more than the opposite hand (Bechtol, 1954; Petersen, 1989).

Table 4 Strength data comparison (%difference) between mean values of male and female agricultural workers

Strength Parameter	<30 yr		30-40 yr		>40 yr		Whole group	
	%diff.	t-value	%diff.	t-value	%diff.	t-value	%diff.	t-value
Dominant hand	35.86	7.215*	36.50	6.091*	31.81	5.864*	34.41	10.712*
Opposite hand	35.38	6.430*	42.43	7.016*	44.75	6.576*	39.98	11.069*

Note: %diff. = 100×(male strength data-female strength data)/male strength data ; *= difference is significant at p<0.05

Muscular strength is generally expressed in either absolute or relative measurements. Absolute measurements refer to the external load commonly expressed in kg and N whereas relative value is expressed in relation to body weight. The expression of strength relative values (kg/kg of body mass) is sometimes more useful to draw a conclusion about muscular power when a comparison is made between individuals. However, absolute measurements of strength values are preferred for comparison made for the same person under different conditions or at different times (Plowman and Smith, 2013). Handgrip strengths (% of body weight) for dominant and opposite hands for male and female of all age groups under study are plotted in Figure 3.

It is observed from the above graph that dominant hand force is found higher when compared with the opposite hand for both gender groups. Further, males are stronger than females as muscle strength are more in case of male in general. The probability at 95% confidence interval and box plot (Figure 4) showed that the distribution pattern of data followed normal distribution approximately and the mean values of males were significantly higher than females.

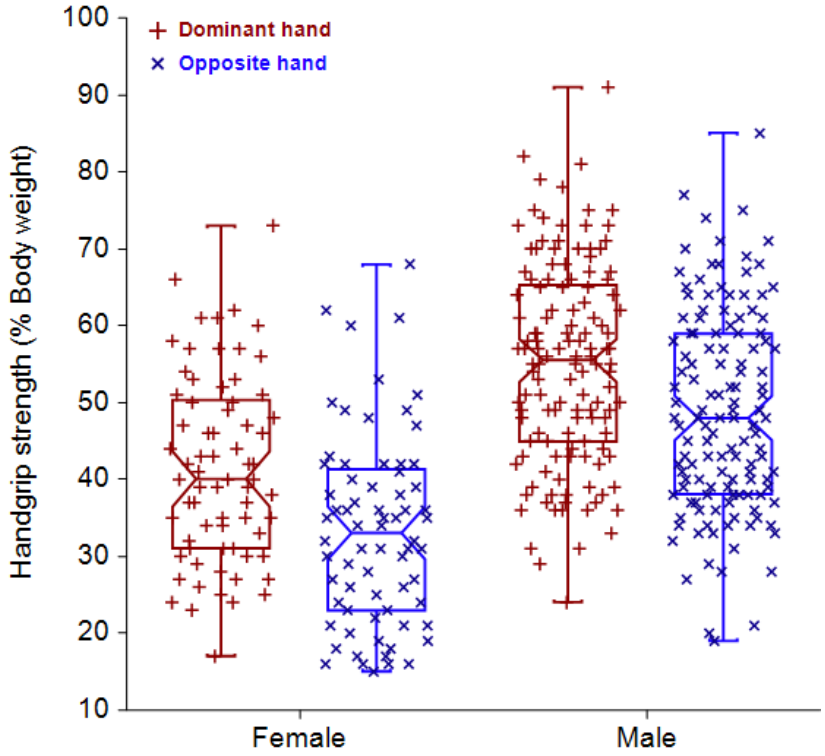

Figure3 Scattered and box plots of handgrip strength expressed relative to body weight for both male and female

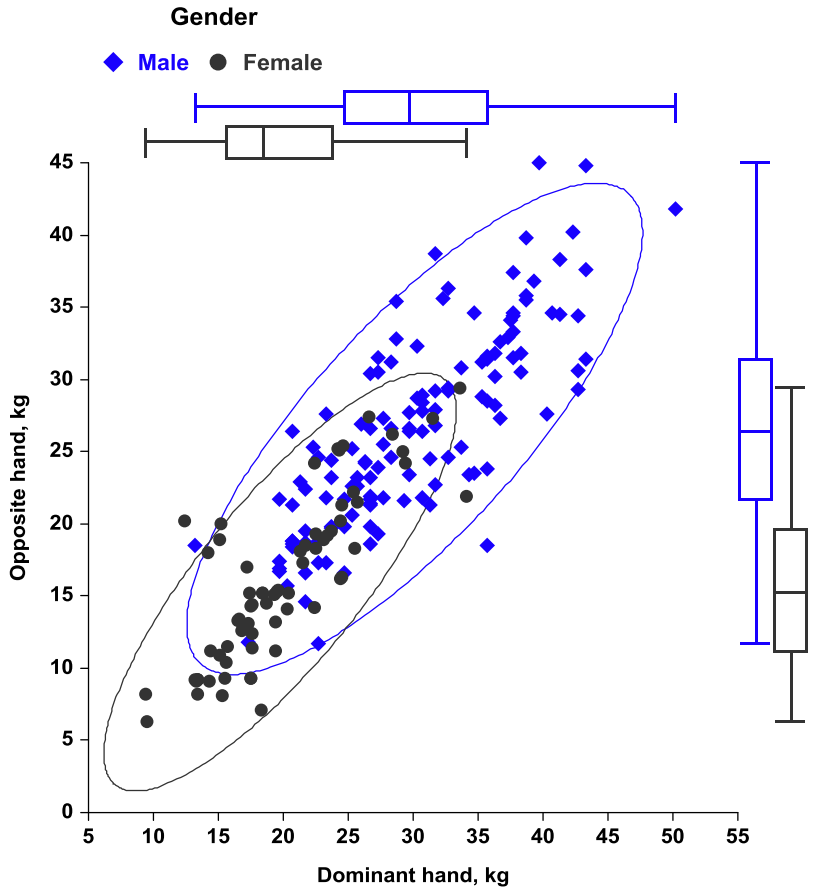

Figure 4Box and 95th percentile probability plots of handgrip strength

At 95% probability, common zones (overlaps) for male and female handgrip strength values were found unable to accommodate a wider range of both male and female data. Therefore, agricultural activities of a repetitive nature executed by both males and females should be designed such that the force requirement does not exceed 30% of the 5thpercentile value of maximum strength capability of female workers. This would ensure force requirement not exceeding safe limits. Force exertion may rise up to 50% as long as the effort is not prolonged for more than five minutes (Agrawal et al., 2009; Gite et al., 2009; Tiwari et al., 2010). Therefore, recommended value for grip strength for male and female agricultural workers of Assam should be 5th percentile of female data which are 10.90 kg for dominant hand and 6.52 kg for opposite hand. However, if the tools and equipment are to be used exclusively by male agricultural workers, recommended values for grip strength should be 5th percentile value of male workers which are 18.50 kg for dominant hand and 15.33 kg for opposite hand respectively. In some work situations where tools and equipment are designed as per 5th percentile mean values of male strength data and female workers are supposed to use the same occasionally, then sufficient rest pause must be provided for female user to avoid any kind of musculoskeletal disorders and injuries.

The cumulative percentage distribution of handgrip strength for male and female dominant and opposite hands respectively is shown in Figure 5. From the graph it is observed that 90% of the right and left handgrip strengths of females were about 32% and 35% of right and left handgrip strengths of their male counter parts. The mean value of right (34.1 kg) and left (29.4 kg) handgrip strength of female was about 2/3rd of right (50.2 kg) and left (45.0 kg) handgrip strength of male workers. Patel et al. (2014) compared sixteen strength parameters including dominant and opposite hands grip forces of pooled Indian data with regional data from various states viz.,Gujarat, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu, Meghalaya and Arunachal Pradesh. They reported that average muscular strength of female is significantly lower (in general 2/3rd of male) than their male counter parts across all states.Therefore, knowledge of basic understanding of human abilities, limitations, and other characteristics which are relevant to tools and equipment design are utmost important.

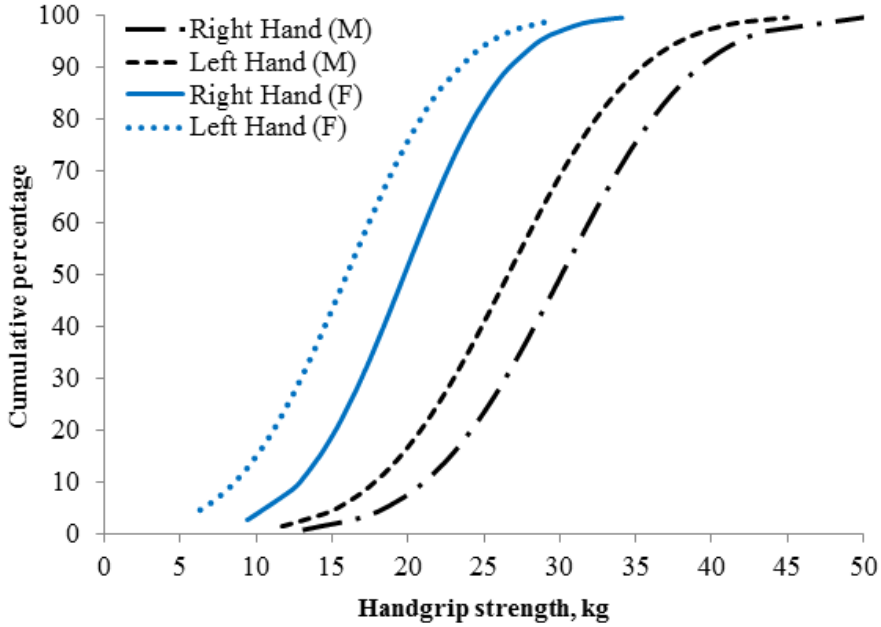

Figure 5 Cumulative percentage distribution of handgrip force for male (M) and female (F) workers

For design/design modification of tools and equipment which are operated by both males and females, operating grip force requirement should not exceed 30% of the 5^{th}percentile value of maximum strength capability of female workers to ensure wider range of coverage as stated above. However, minimum effort requirement should not be too low as to make control difficult for a strongest person. Variability for accommodating the wide range of population may exacerbate existing design problems. In such cases, design should focus on separate design criteria for male and female workers.

5 Conclusions

Isometric handgrip strengths (right and left hand) of 200 (130 male and 70 female) healthy agricultural workers have been reported in present paper with detailed interpretation following statistical analysis and graphical representation. Comparisons between mean values of handgrip strength of agricultural workers of Assam and the other regions of India, indicated that the data of Assamese population differ significantly ($p< 0.01$, $p<0.05$) in most of the cases. These significant differences in strength capability of Assamese agricultural workers (either male or female) with other states of India, clearly verdicts that tools/equipment to be used by Assamese agricultural workers should be designed only by giving due importance of local strength database. The strength database of Assamese agricultural population presented in current paper would serve as a basic reference for isometric strength data of aforesaid population. Thus, bridging of the gap of unavailability of isometric handgrip strength data of Assamese population would help in agricultural tools/equipment design suitable for the said population to reduce manual effort and subsequently to mitigate accident and injuries due to over exertion. Authors propose an exhaustive data collection taking larger representative sample from all districts of the Assam state to establish true baseline reference values.

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