

Analytical study of strength parameters of Indian farm workers and its implication in equipment design

Rajvir Yadav¹, Sahastrarashmi Pund², N. C. Patel³, L. P. Gite⁴

(1. Department of Farm Machinery & Power, College of Agril. Engg. & Tech., JAU Junagadh 362001 India;

2. R&D Center, Mahindra & Mahindra Ltd., Nashik, India;

3. Junagadh Agricultural University, Junagadh 362001 India;

4. CIAE, Nabi Baug Bhopal, India)

Abstract: Among the recent trends in development of agricultural mechanization there are an increase in power and energy capacity of tractors, agricultural machines and equipments, an increase in their reliability and decrease in exploitation expenses and labour consumption. Reliability of agricultural equipments is greatly enhanced provided it is designed with due consideration to the strength parameters of target users / operators. Therefore, strength parameters of 105 agricultural workers (75 male and 30 female) were measured on “strength measurement setup” comprising load cell with digital indicator. The average push strength for male and female workers (with both hands in standing posture) was found to be 248.2 and 171.0 N respectively whereas the pull strength in standing posture was 232.3 and 141.7 N respectively. These strength parameters were found to play a significant role in design of manually operated push-pull type equipment. The right hand push and pull strength for male and female agricultural workers are within the range of 49.7 to 96.5 N which prominently assist in the design of joystick, gear shift lever and handle lever. The mean value of maximum right leg strength in sitting posture for male and female workers are 394.2 and 280.5 N respectively which are found useful in the design of clutch pedal, brake pedal, accelerator pedal, pedal operated thresher and other foot operated controls. Average torque strength of both hands in standing posture for male and female workers are found to be 209.93 and 117.72 N-m respectively which can be used in the design of manually operated equipment like chaff cutter, sugarcane crusher, slicer, threshers etc. Torque strength of preferred hand in sitting posture and hand grip torque worked out in this study for both male and female workers are found very much useful in design of hand controls such as steering, knobs, etc. These strength parameters are found to play a significant role in design/modification of hand controls and foot controls on different workplaces of machines. The machine workplaces designed on strength parameter data are found to greatly enhance the operator’s comfort, safety and efficiency as well.

Keywords: strength and torque parameters, ergonomics, safety, agricultural equipment

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1 Introduction

Ergonomic dimensions correspond best to the orientation of the designed hardware which is registered in different positions and postures that simulate the real working postures and positions in the conventional form (Vos, 1973). Hence, to achieve better efficiency, human comfort and safety, it is necessary to design the

equipment keeping in view the operator’s capabilities and limitations. In Indian agriculture, along with men workers women also play a significant and crucial role in agricultural operations, including different crop production activities, post harvest activities, etc. The workforce engaged in agricultural and allied activities is estimated at more than 200 million of which 70 per cent are male workers. They are devoting many hours in the field but their work is not given due credit. While being an integral and crucial part of the agricultural system, women do not have an access to new agricultural

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Corresponding author’s email: ryadav61@gmail.com, rajvir_yadav1961@yahoo.co.in

technologies that could have save their tremendous amount of time and back breaking labour (Cherian, Vats and Dixit, 2000). The use of female anthropometric data along with those of male can help in the proper designing of the equipment for better efficiency, safety and human comfort (Yadav et al., 2000). With the advent of technology, disregard for the human factor is no longer possible and a knowledge of man's size and its variability has become progressively more critical in designing farm equipment and workplaces (Woodson and Conover, 1973).

Manually operated equipment is extensively used in Indian agriculture for various farm operations starting from seedbed preparation to post-harvest operations. Nag, Astekar and Pradhan (1988) analyzed the effect of sickle design on manual harvesting and the harvester. The performance of the study was justified by the claim that manual harvesting was a moderately heavy task, which required the worker to adopt many awkward postures.

In western countries, a large amount of anthropometric data is available for reference and use (NASA, 1978). Some of the research institutions are now generating and maintaining the database of strength parameters for both the classes of workers, male and female. Anthropometric data bank assembled and maintained by Aerospace Medical Research Laboratories, Dayton, Ohio (USA) is the largest single repository of raw anthropometric data in the world. ERGODATA is another data bank located at Anthropology Laboratory of Paris University of France. However, it does not contain any data about Indian (Asian) population. Mehta et al. (2007) conducted a study to quantify human strength in the operation of tractor controls by Indian operators and concluded the limits for maximum actuating force for brake and clutch pedals should be 330 and 280 N and conducted their study on subjective comfort perception of clutch pedal operation, and possible correlations between subjective rating and biomechanical parameters such as joint angle, moment and work for a better understanding of discomfort. Xuguang et al. (2004) studied the influence of four main design parameters of clutch pedal (seat height, pedal

travel, pedal travel inclination, pedal resistance) by using a multi-adjustable experimental driving package. Comfort was evaluated by using a general comfort rating scale. The relationship between comfort rating and biomechanical parameters was explored. Globally, the results from the biomechanical evaluation of comfort/discomfort are consistent with those from the subjective evaluation. There are very few studies available on Indian farm workers referring to their different strength parameters. This paper reports comprehensive strength parameter database of male and female agricultural workers of Saurashtra, Gujarat (India) for the ergonomic and efficient design, and modifications of agricultural equipment and machineries.

2 Materials and methods

Considering design requirements of controls (hand, foot and leg) in hand tools, animal drawn equipment, tractors, power tillers, power operated machines, self propelled machines and workplaces, a total 14 strength parameters of male and female workers of Saurashtra, Gujarat (India) had been identified for inclusion in the study (Table 1 and 2). For design purposes, either one of the boundary values (5th or 95th percentile) or mean value was used depending upon the dimensional element. All the subjects were free from physical abnormalities and muscular-skeletal problems. If the equipment is to be operated by women, the strength data of the female must be considered in the design along with male strength data. Male and female strength data of the Saurashtra region may be useful in design/modification of agricultural equipment and machines generally adopted in this region. The randomly selected subjects were having age (ranging from 18–55 years), weight (ranging from 45–70 kg), stature (ranging from 145–170 cm) and were familiar with tractor operation and agricultural work.

Table 1 Strength parameters of male farm workers considered in the study with its reference code number

Code No.	Strength Parameters
1	Push strength with both hands in standing posture, N
2	Pull strength with both hands in standing posture, N
3	Right hand pull strength in sitting posture, N
4	Left hand pull strength in sitting posture, N
5	Right hand push strength in sitting posture, N

7	Maximum left leg strength in sitting posture, N
8	Maximum right leg strength in sitting posture, N
9	Maximum left foot strength in sitting posture, N
10	Maximum right foot strength in sitting posture, N
11	Torque strength of preferred hand in standing posture, N-m
12	Torque strength of both hands in standing posture, N-m
13	Torque strength of preferred hand in sitting posture, N-m
14	Hand grip torque, N-m

Table 2 Strength parameters of female farm workers with its code numbers

Code No.	Strength Parameters
1	Push strength with both hands in standing posture, N
2	Pull strength with both hands in standing posture, N
3	Right hand pull strength in sitting posture, N
4	Left hand pull strength in sitting posture, N
5	Right hand push strength in sitting posture, N
6	Left hand push strength in sitting posture, N
7	Maximum left leg strength in sitting posture, N
8	Maximum right leg strength in sitting posture, N
9	Maximum left foot strength in sitting posture, N
10	Maximum right foot strength in sitting posture, N
11	Torque strength of preferred hand in standing posture, N.m
12	Torque strength of both hands in standing posture, N.m
13	Torque strength of preferred hand in sitting posture, N.m
14	Hand grip torque, N.m

Strength parameters of male and female agricultural workers in different postures were measured on “strength measurement set-up” (Figure 1) developed at Central Institute of Agricultural Engineering, Bhopal, India. Steering wheel column angle was simulated to the angle given/set on standard tractors. Steering wheel column angle was about 64° with the horizontal axis and steering wheel rim diameter was 44 cm. The seat height from the base of the rig is 38 cm. The width and depth of the seat were 45 and 30 cm respectively. Total back rest height of the seat was 47 cm from SRP (39 cm back rest and 8 cm open) and having seat pan tilt of 5° backward. In place of seat cushion 2.5 cm plywood was used. A 2,500 N load cell (Novatech make) with digital load indicator was used for measuring the thrust exerted on the pedals by the selected operator and average of repetitions was considered to analyze the result (Figure 2 to Figure 4). Set-up could be adjusted up to 110 cm in front of seat reference point (SRP) and 57 cm below SRP for the position of foot pedal. Due attention was also given while adopting standard terminologies and measurement

technique.



Figure 1 Strength measurement set-up



Figure 2 Torque Strength Measurement of both hands in sitting posture



Figure 3 Pull strength measurement of both hand in standing posture



Figure 4 Right leg measurement in sitting posture

The range of distances covered the range of pedal locations with respect to SRP as recommended by the Bureau of Indian Standards (IS: 12343, 1998). The load cell fixture was adjusted radially in such a way that the angle between foot to lower leg was about 90° . Each of the subject applied his maximum leg strength on the foot pedal within first 2 s and then maintained it for next 3 s while holding the steering wheel and getting support from

the backrest (Kumar, 1991). The average value of leg strength during the last 3 s of 5 s trial was taken for analysis. The male and female observer was given enough practice to measure all the dimensions in a good posture and in a precise manner. The subjects were acclimatized with the experimental protocol for proper and correct measurement.

3 Results and discussion

The hand, leg and foot strength parameters of 105 agricultural workers (75 male and 30 female) were measured in standing and sitting posture and the comparative disclosure had been made in Figures 5 and 6.

3.1 Hand strength

It is need of the hour to design the hand operated equipments considering ergonomical aspects such as anthropometric data and strength parameters. Handle height, length of handle, handle inclination, etc are the key design elements to be considered so that maximum force can be exerted to operate the equipment with less effort and higher comfort and work output from the operator. The average push strength with both hands in standing posture for male and female workers was found to be 248.2 and 171.0 N respectively where as pull strength in standing posture was 232.3 and 141.7 N respectively which can be used in design of wheel hoe,

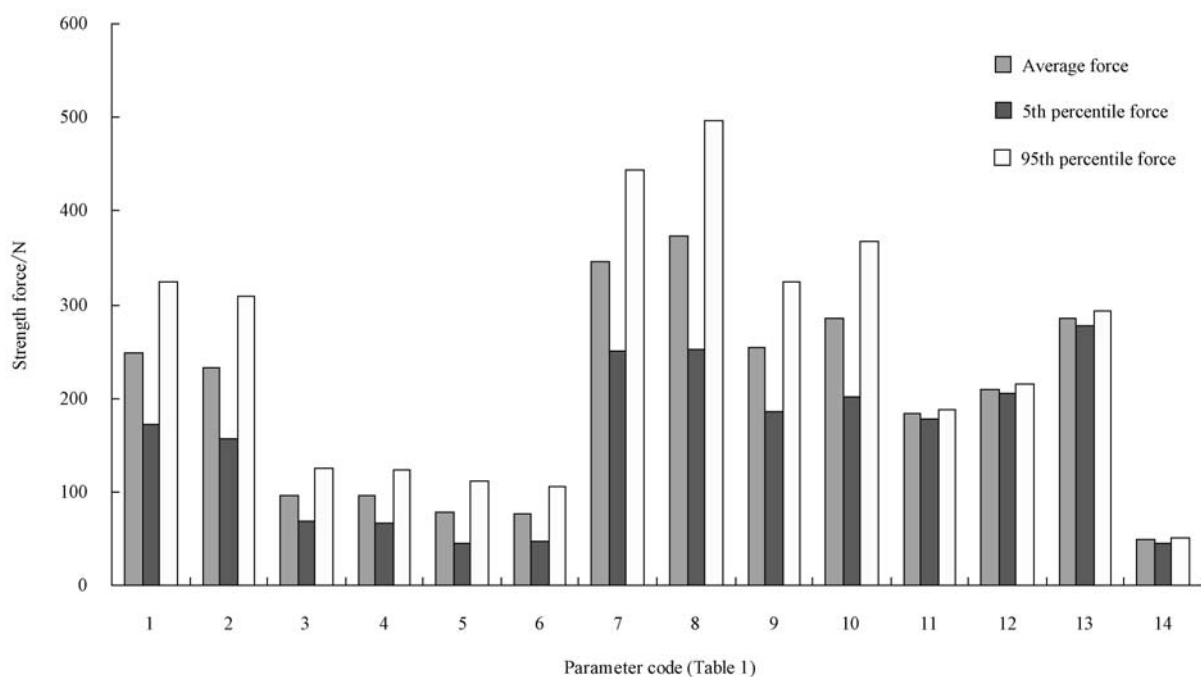


Figure 5 Comparative presentation of strength parameters of male workers

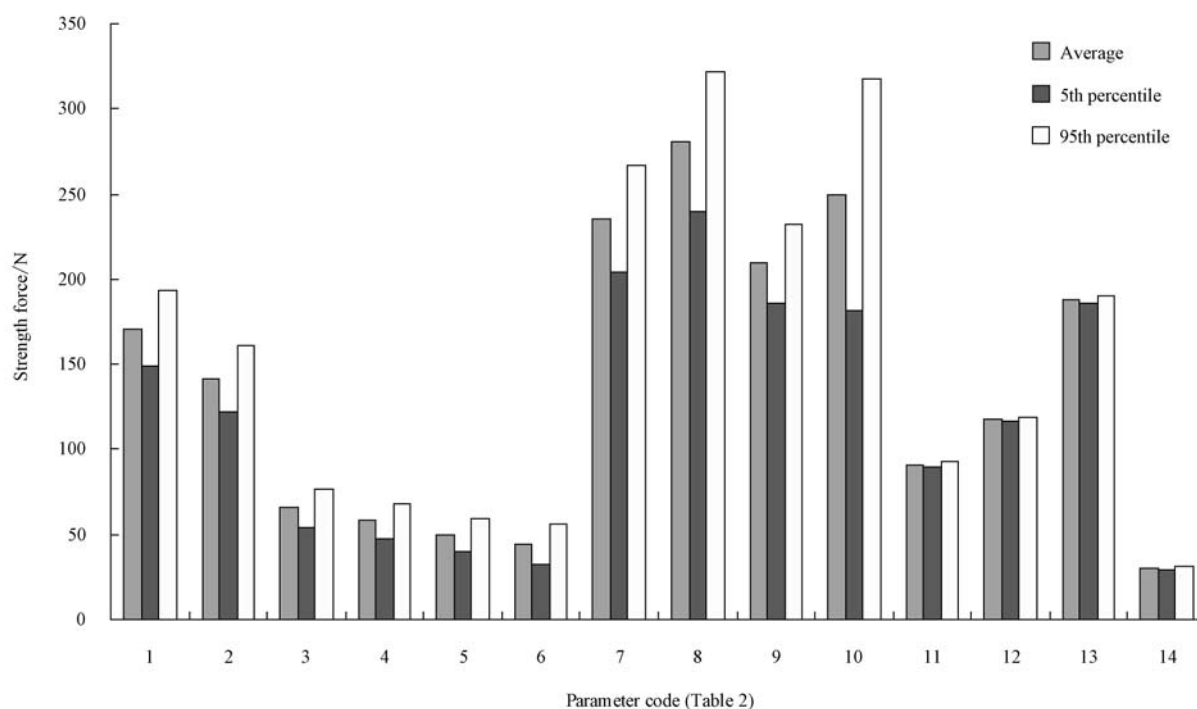


Figure 6 Comparative presentation of strength parameters of female workers

lawn mower and manually operated push and pull equipment. For the design of the joystick, gear shift lever and handle lever, the right hand push and pull strength data of male and female agricultural workers can be utilized which were found within the range of 49.7 to 96.5 N. The maximum value of right hand pull strength in sitting posture for 5th and 95th percentile of male workers were 68.7 and 124.2 N and for female workers they were 54.4 and 77.0 N which play dominant role in designing of joystick, gearshift lever, handle lever, workplace design, etc.

3.2 Leg and foot strength

Leg and foot operated controls on workspace of machinery & equipments such as the foot operated sprayers, threshers, dibblers are prominently used in the Indian agriculture. The 5th percentile values of male workers for leg and foot strength were 250.7 and 185.7 N and for female workers 204.2 and 181.8 N respectively that can be effectively used for the design purpose. The maximum foot strength of male and female agricultural workers were 285.0 and 249.8 N respectively, which is useful in the design of accelerator pedal, clutch pedal, brake pedal and similar other foot-operated controls.

3.3 Torque strength

The mean torque strength by both hands in standing

posture of male and female workers were found to be 209.93 and 117.72 N-m respectively which can be used in the design of manually operated equipment like chaff cutter, slicers, threshers and sugarcane crusher. Torque strength by both hands in standing and sitting postures are used in the design of manually operated equipments like chaff cutter, sugarcane crusher and design of control viz. steering. The 5th and 95th percentile values of torque strength of preferred hand in standing posture were 178.57 and 188.33 Nm for male and 89.51 and 92.17 Nm for female workers respectively and similarly in sitting posture were 276.86 and 292.52 N for male and 185.77 and 190.15 Nm for female workers respectively that should be considered in user friendly design of the steering wheel of tractor and/or other vehicles. For efficient and effective design of control knob, sprayer lids and opening cover of service point, the mean hand grip torque of 48.17 Nm for men workers and 30.41 Nm for female workers should be considered. These overall strength parameters can be used in the design/modification of hand controls and foot controls like clutch/brake on different workplaces of machines.

4 Conclusions

This study presents compilation of strength parameter

data of male and female workers of Saurashtra region that could be used as a guide for designing and modifying agricultural and industrial equipment suiting to human strength capabilities and limitations. These parameters can be utilized in the design of manually operated push-pull equipment, workplace design, gear shift lever, handle lever, gear control lever, design of pedal for

accelerator, clutch and brake, and other foot operated controls. It is recommended that such extensive surveys for both male and female farm workers should be carried out in different regions of the country in order to generate region specific design database for safe and efficient design / modification of agricultural equipment.

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