Isometric torque affected by its position and posture

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Abstract: A hand cranking mechanical frictional setup was developed using anthropometric dimensions of Madhya Pradesh farm women. The setup had a provision for attaching on-line torque transducer. Variable crank length was provided that could be adjusted as per the farm women (workers). The setup had also a provision for rising up and down to match workers' conditions. Isometric torque was measured at each quadrant positions of handle (0°, 90°, 180° and 270°) at different crank lengths (17.5, 21, 24, 27 and 30 cm). Higher torque was developed by farm women in standing posture as compared to sitting. The crank length up to 27 cm gave better torque at nearly all positions. The lowest torque may be considered for designing the equipment amongst all positions of handle so that human being could easily operate the equipment.

Keywords: isometric torque, hand cranking, farm women, crank length, position, posture

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1 Introduction

Human being performed hand cranking with one or two arms. Two arms hand cranking is preferred mostly for such activities where torque requirement is high. Hand cranking is performed at different working heights by human beings, i.e., in bending position (starting diesel engine and operating chaff cutter), in sitting position (operating sewing machine) and in standing position (operating sprayer, winnower etc.). The torque requirement varied from low to high depending on type of agricultural activities viz. winnowing and mixing seed with seed treatment drum, broadcasting with broadcaster, spraying with sprayer, chaff cutting with chaff cutter, etc. Human being generated a specified level of torque with elbow flexor muscles of one arm. The torque at fixed position (isometric) would be different at each quadrant in clockwise direction. The maximum force that a human being can exert is cranking cannot exceed the body weight; otherwise crank could not be moved in a downward direction. The rate of cranking will decrease as the load increases (Murrel, 1965). Das and Bhattarcharya (1984) reported arm reaching for optimum crank length of the rotary device during cranking mode of working with both hands was 30%. Increase of heart rate during hand cranking was minimum when the horizontal location of a rotary device was 77% of arm reach and the vertical location is 77% of shoulder height. Nag (1984) reported that the maximal power output for arm work while standing was about 25% to 30% less than that found in a sitting posture. Raouf, A., H. Imanishi, and K. Morooka (1986) indicated the superiority of a clockwise turning direction and effect of radius, torque, and plane angle were found to be significant. In this paper an attempt was made to know the level of torque (isometric) developed by farm women in standing and sitting postures and analysed its implication on design of equipment to be operated by hand(s).

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2 Materials and methods

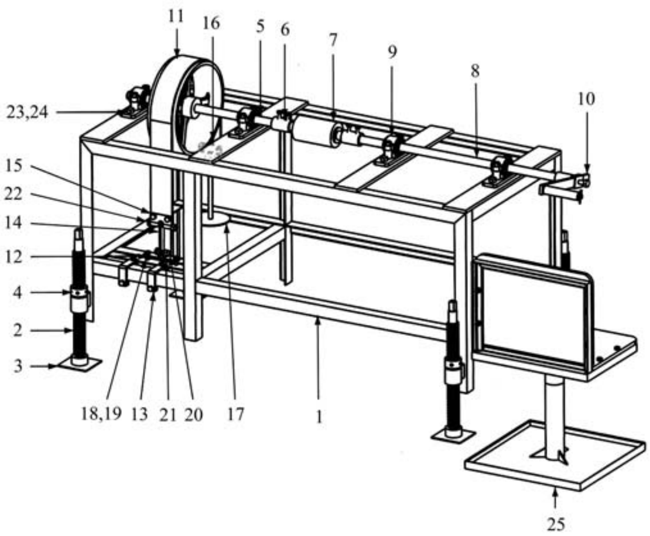
2.1 Hand cranking setup

A mechanical hand cranking frictional setup has been developed based on anthropometric data of Madhya Pradesh farm women (Table 1). Length of setup was kept at 1,365 mm to accommodate the torque transducer for recording the torque. Adjustment was provided with help of simple screw jack at four corners for raising the setup. This helped in adjusting the farm women. A handle with variable crank length (175 to 300 mm) was provided. Length of handle for palm gripping was kept at 130 mm to provide free adjustment of palm of worker during cranking. This value was obtained after adding 30% in the dimension of hand breadth across thumb, because this dimension is measured at the level of distal end of the 1st metacarpal of the thumb. Diameter of handle was taken at 25 mm. The body dimensions considered for the design of chair were sitting popliteal height, hip breadth sitting, buttock - popliteal length, interscye breadth and elbow rest height. Chair was consisted of seat pan, seat back rest and screw jack for height adjustment. The length of seat pan was decided based on 5th percentile buttock-popliteal length (horizontal distance from the rear most surface of the buttock to the back of the lower cap). Thus, dimension was kept about 10% less than the value and kept at 350 mm. Seat pan's width was 410 mm which was about 15% higher to 95th percentile hip breadth sitting to adjust different type of workers. During hand cranking in sitting posture, arm(s) should move freely therefore, interscye breadth was considered and by adding 10%, dimension was kept at 350 mm. Length of back rest was kept about 20% higher than 95th percentile elbow rest height for accommodating most of the women workers and also to provide ease in movement of their arms. Thus size of back rest seat (350 mm in width and 290 mm in length) was finalized. Seat height was decided based on 5th percentile sitting popliteal height, as this dimension was measured from above the footrest surface to underside of the leg (below knee) and design requirement was not to touch the underside of leg. Thus dimension for seat height was considered about 10% less than this value. To accommodate most of the farm women, height of chair was made adjustable using simple screw jack. Using the dimension, computer aided design of the setup was made and unit was fabricated. The orthogonal view of the setup is shown in Figure 1.

Table 1 Dimensions considered for hand cranking frictional setup and chair

No.	Dimensions	Anthropometric dimensions taken	Value* /mm	Finalised value /mm
A		Cranking setup		
1.	Width	Shoulder grip length- 5th	600	600
2.	Height	Metacarpal-III height- 5th - 95th	603 721	600 (Adjustable up to 850)
3.	Palm grip on handle	Hand breadth across thumb- 95th	99	130
4.	Diameter of handle for gripping	Middle finger palm grip dia - 5th - 95th	23 33	25
B		Chair		
5.	Length of seat pan	Buttock-popliteal length- 5th	404	350
6.	Width of seat pan	Hip breadth sitting- 95th	353	410
7.	Width of seat back rest	Interscye breadth- 95th	324	350
8.	Length of back rest	Elbow rest height- 95th	242	290
9.	Seat height	Sitting popliteal height- 5th - 95th	350 433	315 (Adjustable up to 550)

Note: * Agarwal et al. (2007).



1. Main frame 2. Plain screw jack 3. Screw jack assembly 4. Screw jack nut 5. Shaft bearing assembly 6. Torque meter bush 7. Torque meter assembly 8. Main shaft 9. Bearing block 10. Handle assembly 11. Flat belt 12. Bracket 13. Clamp 14. Connecting flat 15. Hinge bracket assembly 16. Hanging bracket assembly 17. Hanger assembly 18. Bolt 19. Nut 20. Bolt 21. Nut 22. Bolt 23. Bolt 24. Nut 25. Operator seat assembly

Figure 1 Orthogonal view of hand cranking mechanical frictional setup

2.2 Experimental detail

Four quadrant positions of handle were selected viz. top (0°), front (90°), bottom (180°) and back side (270°) to know the torque at each position (Figure 2). Five crank lengths (175, 210, 240, 270 and 300 mm) were taken to measure the torque at each quadrant position of handle. Torque transducer of EEL make, England was attached on-line in experimental setup for measuring shaft torque. The recorder (Datum Electronics, Newport) was connected to the torque transducer and electric point. Prior conducting experiment, torque transducer was calibrated by hanging known weight on handle of cranking shaft. Pulley was locked at each selected position of handle and isometric torque developed by the subject at each crank length was recorded. Eleven farm women participated in this experiment. Age, heights, weights and related body dimensions were measured.

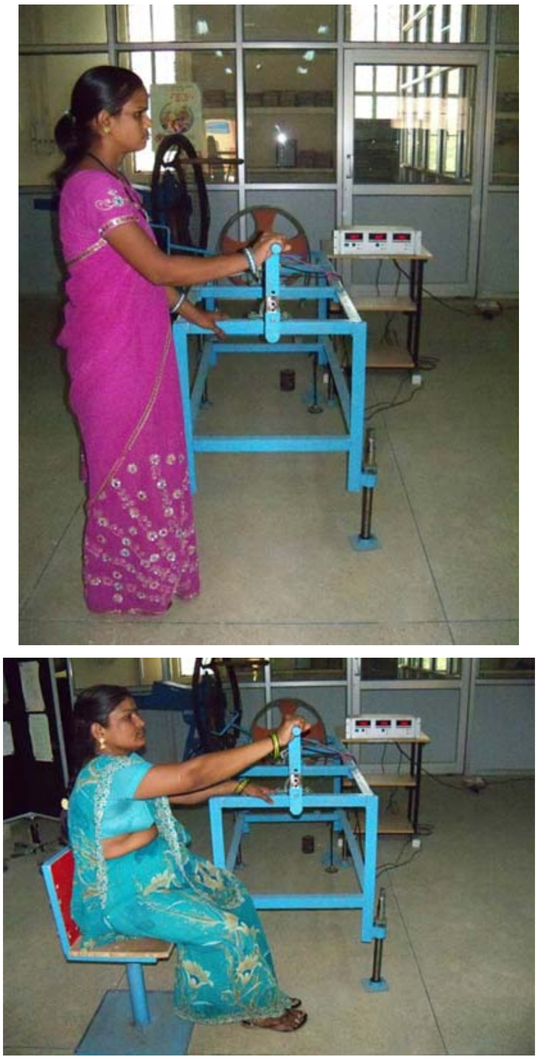


Figure 2 Force exerted by farm woman in standing and sitting postures at top positions of handle

Measurement of torque was done in standing and sitting postures. The placement of subject was kept in such a way that their arms almost fully extended when the crank handle was at their greatest distance (90°) during both postures. The position of hand during this experiment was pronation (Figure 2). Three readings at each position and crank length were taken, and average value was calculated.

Effect of handle position and crank length on isometric torque developed by the subjects in standing and sitting postures was assessed using ANOVA two factors. Similarly effect of posture on isometric torque at various crank lengths for different handle positions was also assessed.

The average (±S.D) age, height and weight of participated farm women were 33.5±5.7 yr, 1.52±0.05 m and 50.3±9.2 kg respectively. Upper and lower arm muscle circumferences were 245.5±24.6 and 223.2±15.5 mm, respectively.

3 Results and discussion

3.1 Effect of crank length on isometric torque in standing posture

The isometric torque during pronation position of hand at different handle position and crank length in standing posture is given in Table 2. The highest isometric torque was found at 30 cm crank length as compared to other selected crank lengths for all measured positions of handle. Isometric torque at 30 cm crank length was significantly higher at 5% level in comparison to the torque obtained at crank lengths of 27, 24, 21 and 17.5 cm. Percent increase in torque at 30 cm crank length was 0.5% to 6.7% at different positions of handle while it was 14.5% to 22.2% at crank length of 27 cm. Thus, it indicated restricting the crank length up to 27 cm. The lowest torque was found at 90° when handle was at its greatest distance. Maximum torque was at bottom side followed by back side, top and front side. The variation in torque obtained at top, back side and bottom side of handle was 18% to 72% higher than obtained at front side. This clearly indicated the importance of measuring the torque at different quadrant positions of handle because for design criteria 30% of maximum strength is considered as per Grandjean (1982). Therefore, study suggested considering the value obtained at front position of handle which was at greatest distance during hand cranking.

Table 2 Isometric torque at different crank length on various handle position in standing posture

Position of handle from ground/(°)	Isometric torque/N m				
	Crank lengths/cm				
	17.5	21	24	27	30
Top (0°)	23.00	27.55	32.00	36.64	36.82
Front side (90°)	17.73	23.27	25.00	30.55	32.55
Bottom (180°)	30.18	35.73	43.73	51.36	54.82
Back side (270°)	30.45	36.91	40.00	47.18	50.36

The isometric torque increased with increase in crank length from 17.5 to 30 cm at top (0°), front side (90°), bottom (180°) and back side (270°) positions of handle (Figure 3). The polynomial trend obtained in graph indicated the declining tendency in increaments of isometric torque after crank length of 27 cm for all positions of handle except its bottom position. This might be due to less effect of hand at increasing crank length on the torque obtained from a fixed position of subject.

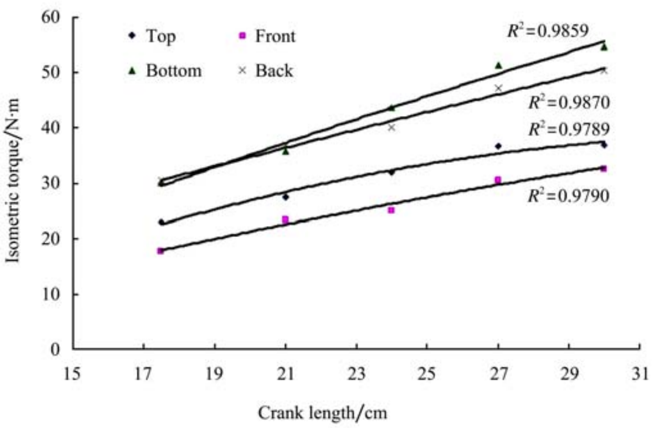


Figure 3 Relationship between isometric torque and crank length at different handle position in standing posture

The relation between isometric torque and crank length at different handle positions from ground (top, front, bottom and back side) in standing posture was established using linear, logarithmic, power, exponential and polynomial trends. The higher value of coefficient of determinant (R^2) suggested polynomial trend. Thus, polynomial best fit equation is given as Equation (1) to (4). The higher value of R^2 (0.9789 to 0.987) suggested that the equations could be used for estimating the isometric torque at different handle positions for crank length in standing posture.

Top (0°): $y = -0.0513x^2 + 3.6229x - 25.113$ (1)

Front side (90°): $y = -0.0157x^2 + 1.9387x - 11.248$ (2)

Bottom (180°) : $y = -0.0144x^2 + 2.7737x - 14.648$ (3)

Back side (270°): $y = -0.0065x^2 + 1.9236x - 1.1792$ (4)

where, x = crank length, cm and y = torque on shaft in standing posture, N m.

3.2 Effect of crank length on isometric torque in sitting posture

The highest isometric torque in sitting posture was also found at 30 cm crank length similar to standing posture (Table 3). The average isometric torque at bottom position was significantly higher at 5% cent level as compared to the isometric torque obtained at handle positions of 0°, 270° and 90°. The torque at 30 cm crank length was significantly higher as compared to the isometric torque obtained from crank lengths of 27, 24, 21 and 17.5 cm. Lowest torque was obtained when handle was at 90° (greatest distance) for all crank lengths.

Table 3 Isometric torque at different crank length for various handle position in sitting posture

Position of handle from ground/(°)	Isometric torque/N m				
	Crank length/cm				
	17.5	21	24	27	30
Top (0°)	22.09	25.00	28.64	33.82	34.18
Front side (90°)	14.82	17.55	19.45	22.27	24.00
Bottom (180°)	31.73	33.45	40.55	47.55	53.27
Back side (270°)	18.91	25.09	27.82	32.73	38.18

The isometric torque increased with increase in crank length from 17.5 to 30 cm at top (0°), front side (90°), bottom (180°) and back side (270°) positions of handle in sitting posture (Figure 4). The trendline of graph again indicated the declining tendency in increaments of isometric torque after crank length of 27 cm at top position of handle. This might be due to more angle formation between lower and upper arms with increase in crank length during top position of handle as it is known that more flexion of hand affect the ability of subject in producing more force from same place. Using linear, logarithmic, power, exponential and polynomial trends, the relation between isometric torque and crank length at different handle positions in sitting posture was established. The higher value of coefficient of determinant (R^2) was obtained with polynomial and, thus, polynomial best fit equation is given as Equation (5) to (8). The higher value of R^2 (0.9613 to 0.9964) suggested that the equations could be used for estimating the isometric torque at different handle positions for crank length in sitting posture.

Top (0°): $y = -0.0146x^2 + 1.7587x - 4.651$ (5)

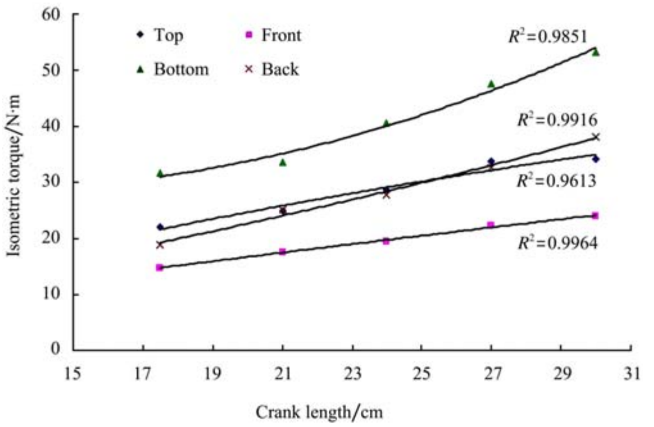


Figure 4 Relationship between isometric torque and crank length at different handle position in sitting posture

Front side (90°): $y = -0.0031x^2 + 0.8962x + 0.036$ (6)

Bottom (180°): $y = 0.0746x^2 - 1.7091x + 38.1$ (7)

Back side (270°): $y = 0.0147x^2 + 0.7951x + 0.8868$ (8)

where, x = crank length, cm and y = torque on shaft in sitting posture, N·m.

3.3 Effect of postures on isometric torque at various crank lengths for different handle positions

Average torque obtained in standing posture was 19.4% higher than sitting. This was in agreement to (Mittal and Faard, 1990). From Figure 5, it is clearly found that the torque was higher in standing posture than sitting for all crank lengths and positions except at crank length of 17.5 cm during bottom position. Highest per cent variation (24% to 38%) in torque was found while handle was at back side followed by front side (16% to 27%), top (4% to 10%) and bottom (3% to 7%) for 21 cm crank length and above. This also clearly indicated that the torque obtained at each quadrant position was affected by their awkward position at back side and greatest distance at front side. One must be very careful for designing the equipment about selection or consideration is value of torque. If torque requirement while operating hand operated equipment is high, designer must go for lowest value of torque obtained at such handle position, posture and crank length.

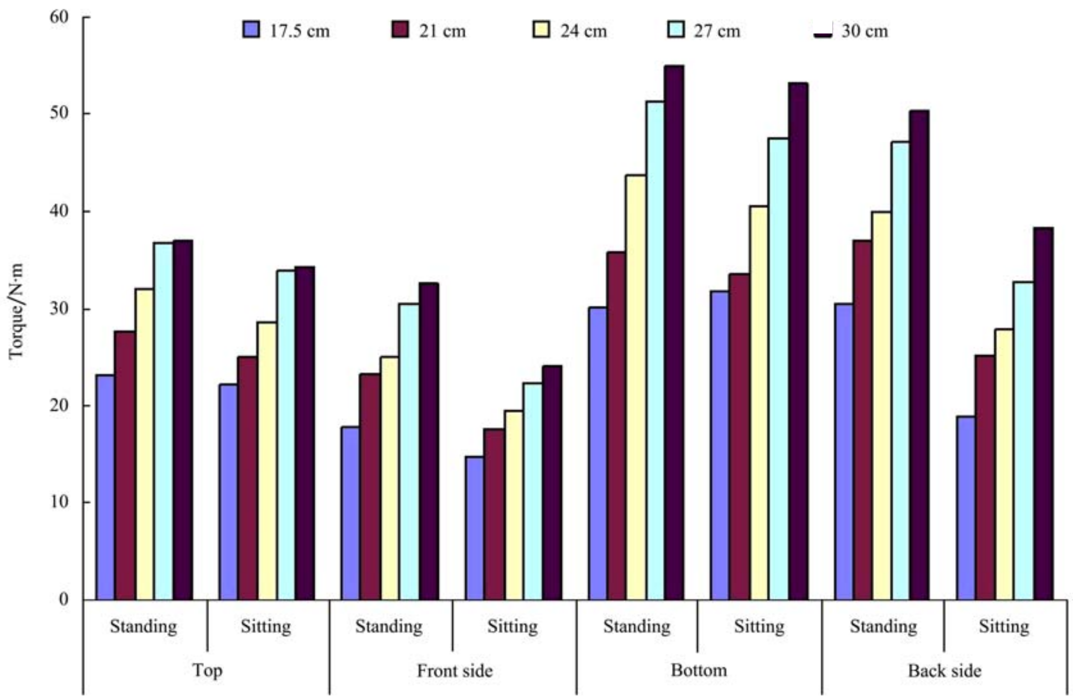


Figure 5 Effect of handle position and postures on isometric torque at various crank lengths

Effect of posture on isometric torque at top (0°), front side (90°), bottom (180°) and back side (270°) positions of handle for different crank lengths was analysed. It was observed that posture did not have significant effect on isometric torque obtained at 5% level while handle was at top and back sides. This might be due to similar flexion of hand with respect to elbow at both positions. However, isometric torque obtained in standing posture at handle position of front side and bottom position of handle was found significantly higher at 5% level as compared to sitting. The average isometric torque developed by the subject was 25.34 to 43.61 N·m at 17.5 to 30 cm crank lengths which was significantly higher in standing posture at 5% level as compared to the isometric torque (21.85 to 37.41 N·m) obtained at these crank lengths in sitting respectively. This might be due to more power developed by the subject in standing posture than sitting as whole body was involved.

4 Conclusions

The study conducted on isometric torque at different crank lengths and position of handle indicated the development of higher torque by farm women in standing posture as compared to the torque obtained in sitting. Isometric torque obtained at nearly all quadrant positions was found better at 27 cm crank length as compared to studied crank lengths (17.5, 21, 24 and 30 cm). The lowest torque amongst all positions of handle may be considered for designing the hand operated farm equipment so that human being could easily operate the equipment.

References

Agarwal, K. N., P. S. Tiwari, L.P. Gite, and V.B. Babu. 2007. *Final Report of Anthropometric Survey of Agricultural Workers of Madhya Pradesh*. Agricultural Mechanization Division, CIAE, Bhopal: 102-103.

Das, H and S. Bhattacharya. 1984. Optimum design and location of a hand operated rotary device. *Journal of Agricultural Engineering (ISAE)*, 21 (3): 29-36.

Grandjean, E. 1982. Fitting the Task to the Man- An Ergonomic Approach. *Taylor and Francis Limited*, London. 28(2): 210.

Mittal, A. and H.F. Faard. 1990. Effects of sitting and standing reach distance, and arm orientation on isokinetic pull strengths in the horizontal plane. *International Journal of Industrial Ergonomics*, 6 (3): 225-331.

Murrel, K.F.H. 1965. Ergonomics: *Man in His Working Environment*. 239-242. London:Chapman and Hall Ltd., .

Nag, P.K., 1984. Circulo-respiratory responses to different muscular exercises. *Europian Journal of Applied Physiology*, 52(4): 393-399.

Raouf, A., H. Imanishi, and K. Morooka. 1986. Investigation pertaining to continuous and intermittent cranking motion. *International Journal of Industrial Ergonomics*, 1(1): 29-36.