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## CONTENTS

# Assessment of physiological characteristics and effect of load on agricultural workers during cranking operation

SWEETI KUMARI[1,2], V.K.TEWARI[2] and SANJEEV KUMAR[3]

*[1]ICAR-Central Institute of Agricultural Engineering, Bhopal- 462 038 (Madhya Pradesh), [2]Agricultural and Food Engineering Department,Indian Institute of Technology, Kharagpur-721 302(West Bengal), [3]CSIR-Central Mechanical Engineering Research Institute, Durgapur-713 209(West Bengal)*

**ABSTRACT:** An investigation was conducted to evaluate agricultural workers' ergonomic performance during cranking activities. To assess the ergonomic performance of agricultural workers, a cranking operation experimental lab set-up was developed based on the subjects' ergonomic reach criteria. Four loads 10, 30, 50, and 70 N were used to assess the ergonomic performance of 12 medically fit male farm workers. For all loads, it was observed that the working heart rates (WHR) of the selected subjects were 102 to 135 beats/min. The limit of continuous performance (LCP) was less than 40 beats/min for all selected loads except at 70 N of load. However, it was also observed that all of the selected subjects' oxygen consumption rates (OCR) varied between 0.59 and 1.19 l/min and their energy expenditure rates (EER) ranged between 12.34 and 24.86 kJ/min for all loads. According to the classification of manual jobs based on energy expenditure during the operation, cranking operation with a 10 N load fell in the light category, whereas 30 and 50 N fell in the moderately heavy category, and 70 N fell under the heavy category Additionally, the overall discomfort ratings (ODR) ranged from 3.1 to 6.3 on the adopted 10-point scale, while the body part discomfort scores (BPDS) for cranking operation of all the selected subjects was obtained in the range of 35.2 to 38.3.

**Key words:** Cranking, energy expenditure rate, oxygen consumption rate, working heart rate

Rotary agricultural machinery is one of small farmers' most useful machinery for animal feed chaff cutting and hand pump operation. The rotary motion of rotary machinery was made with the help of hand and foot, which is called cranking and pedalling, respectively. The cranking operation is defined as the activity of turning a crank lever by hand. However, cranking operation or activity performed with the help of foot is called pedalling operation. Corn shellers, hand chaff cutters, hand-operated maize dehusker- shellers, manual fodder cutters, etc. are examples of agricultural machinery that uses hand cranking (Kumar *et al.,* 2010 and Singh *et al.,* 2012). Upper limb injuries are very common among those who use manual arm cranking. The point prevalence of shoulder pain in people with spinal cord injuries ranges from 30 to 73 per cent (Ballinger *et al.*, 2000), compared to 7 to 27 per cent in the general population (Luime *et al.*, 2004). In persons with chronic spinal cord injuries, musculoskeletal problems, especially overuse injuries to the rotator cuff, are the most common causes of shoulder discomfort (Dyson-Hudson *et al.*, 2007). Cranking operation with the hand is found to be more strenuous than a foot. Hand cranking operation can be performed in both standings as well as in sitting body posture. The standing posture for hand cranking operation is preferred when the torque requirement of machinery is high. Hand cranking is performed at different working heights for different operations. The hand tools have to be held securely with a suitable wrist and arm posture, and without overloading the body, they may use strength and energy capabilities. The torque applied by the operator during cranking operation depends upon many design factors such as cranking radius, workload, the operator's capability to requisite the torque, posture of operators etc. According to Frymoyer *et al.* (1980), excessive cranking and steering torque is responsible for a high physical workload and musculoskeletal issues affecting the lower back and upper extremities. An ergonomic study was conducted to analyse rotary power input by hand and leg muscles during farm equipment operation. This study conducted five posture analysis modes: handle rotation, hand rocking, single foot pedal, dual foot pedal, and foot rotation (cycling) to generate rotary motion in farm machinery (Potdar *et al.*, 2011). The ergonomic assessments suggest that the subject's posture change was frequent during the manually operated fodder cutting machine (Kumar *et al.*, 2010). The one revolution of the subject was found to be completed every two seconds.

A study was designed using hand-cranked tricycle propulsion to assess the physiological cost and occupational performance of people with lower extremity disabilities (Nag *et al.*, 1982). This study enlisted the help of eleven volunteers. At Standard Temperature and

Pressure Dry (STPD), max (arm cranking) was just 777 l/min for an average body weight of 397 kg. The disabled participants' pulmonary demand and oxygen intake during tricycle propulsion were around 70% of their maximum response; thus, occupational stress was classified as heavy. When a hand-rim propulsion system was setup for two-arm cranking at the disabled person's heart level and a cranking speed of 60 rev/min, the mechanical efficiency of cranking was at its peak. Capodaglio and Bazzini (1996) compared a method for predicting endurance capacity at different workloads based on the subjective perception of effort. The task consisted of graded and continuous tests on an arm crank ergometer, during which cardio-respiratory (heart rate, oxygen consumption, ventilation and respiratory exchange ratio) and subjective (Borg's 10-point scale) parameters were monitored continuously. Subjects performed three tests in which the power output remained constant (50, 37.5 and 25 W), leading to muscular fatigue.

Moreover, a study was conducted for ergonomic evaluation of the manually operated paddy transplanter (cranking type) in the puddled field (Aware *et al*., 2015). The working heart rate (HR), oxygen consumption (VO2) and energy expenditure (EER) were found to be 129.18 beats/min, 1.4 l/min and 29.22 kJ/min, respectively. The value of work pulse (DHR), overall discomfort rating (ODR) and body part discomfort score (BPDS) was 39.97 beats/min, 5.83 and 6.5, respectively, which indicated that the manual operated rice transplanter operation was under 'heavy' workload category. The rotary maize dehusker-sheller and ergonomic intervention in their design were made to study the effect on operator health (Singh *et al*., 2012). Tiwari *et al*. (2014) conducted experiments on the design parameters of a pedal-operated rotary device (dynapod). The developed dynapod was interfaced with a hand-operated rotary maize sheller. Hand cranking mode was taken as the comparison parameter to evaluate the performance and drudgery reduction of the developed machine. They found that the output capacity of the machine (282.7 kg/h versus 144.42 kg/h) significantly increase with a significant reduction in work pulses ("HR) during the operation of the machine (35 beats/min versus 59.4 beats/min).

The designer of cranking agricultural equipment with special reference to Indian agricultural workers should thoroughly understand cranking force exertion data to determine the maximum torque the operator applies in a standing position. Most reported studies on cranking operation have either foot or specific machinery operated study, which either involves western population with the specialist working group. The effect of load on agricultural workers during hand-cranking operations with standing posture under laboratory conditions was investigated in the current study for frequent long-duration torque application, as they typically work in the field.

## MATERIALS AND METHODS

### *Development of experimental setup for cranking*

The experimental setup was fully designed according to anthropometric data of the Indian population for the measurement of cranking force and physiological parameters. For the design of the cranking experimental setup, the 5$^{th}$ and 95$^{th}$ percentile values of the following anthropometric parameters of males and females were used: stature, weight, eye height, elbow height, vertical reach, acromial height, vertical grip reach, shoulder grip length, elbow grip length, palm length, hand length, middle finger grip diameter, grip diameter inside, maximum grip length, and grip span. The above-mentioned anthropometric dimensions were chosen from the book "Anthropometric and strength data of Indian agricultural workers for farm equipment" (Gite *et al*., 2009) to design the cranking experimental setup.

For cranking, the handle height of the experimental setup was kept 5$^{th}$ percentile of acromial height of the Indian population. The bending of the selected subjects varies according to their arm reach and shoulder grip length. The arm reach from the wall and shoulder grip length for 5$^{th}$ percentile values was used for handle diameter. The experimental setup for physiological data assessment of selected subjects has comprised of a wooden platform, one flywheel at the one end of the shaft, a handle fitted on the flywheel, five circular holes along the diameter of a flywheel was provided to adjust the height, belt and pulley arrangement at the other end for mounting of the load, and a lift system to adjust the height of flywheel. The BIS has provided a range of flywheel diameters from 900 to 1350 mm. So, the flywheel diameter for cranking was taken 1000 mm outer diameter wheel made of cast iron. The centre of the flywheel was connected with the main shaft. One end of the main shaft was rigidly attached to the centre hole of the flywheel, and another end was supported with a ball bearing on a frame. The length and diameter of the shaft of the experimental setup were 1100 mm and 25 mm, respectively. The flywheel at one end was connected by a central shaft made of 25 mm diameter. A pulley of a diameter of 200 mm was installed for loading weights at other ends of the shaft with an 80 mm width belt. The hanging loads at the other end of the shaft were gradually applied to determine the actuating force under various loading conditions. The developed prototype experimental setup for the evaluation of cranking data of agricultural workers under laboratory conditions is displayed (Fig. 1). The rotation of the crank is transferred to the flywheel through a pair of gears, increasing the rotation speed. The experimental test set-up for the prototype's part dimensions for cranking operations is shown (Table 1).

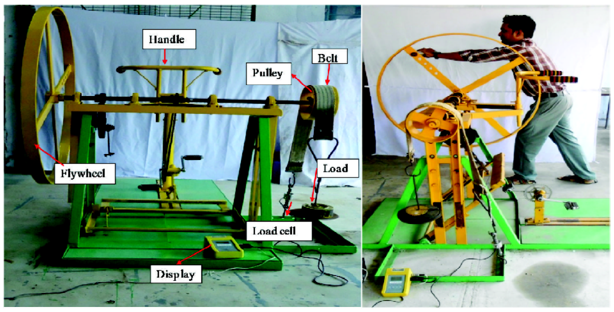


**Fig. 1: Experimental set up for cranking operation for physiological parameter evaluation**

**Table 1: Design dimensions for cranking set-up**

| Sl. No. | Part | Dimension |
|---|---|---|
| 1 | Diameter of flywheel, mm | 1000 |
| 2 | Circular hole diameter at flywheel, mm | 20 |
| 3 | No. of holes | 5 |
| 4 | Hole to hole distance, mm | 50 |
| 5 | Main shaft length, mm | 1100 |
| 6 | Main shaft diameter, mm | 25 |
| 7 | Height of stand (adjustable), mm | 800-1100 |
| 8 | Height of flywheel or main shaft (centre to ground), mm | 800 |
| 9 | Handle diameter, mm | 38 |
| 10 | Total handle length, mm | 650 |
| 11 | Overall length of frame, mm | 2000 |
| 12 | Overall width of frame, mm | 750 |
| 13 | Diameter of load hanging pulley, mm | 200 |
| 14 | Width of load hanging pulley, mm | 100 |

***Selection of subject***

Twelve subjects between the age group of 25 to 40 have been selected for the investigation of physiological characteristics during cranking operation. The maximum strength or power can be expected from the age group of 25 to 35 years (Grandjean, 1980; Gite and Singh, 1997). During experimental observation, it was also observed that all the twelve selected subjects had normal body mass index (BMI) and blood pressure (BP) values. The normal value of BMI and BP indicates that all the twelve selected subjects have normal health and are medically fit for the experimental investigation. Twelve healthy male agricultural workers participated in the experiment having mean age of 34 (± 4.84) years, average weight of 621.55 (± 69.04) N, average stature of 1667.5 (± 55.6) mm and body mass index (BMI) of 22.82 (± 2.01), which were within the normal range (18.5–24.9) as per the World Health Organization (WHO).

***Ergonomic evaluation of the workers during cranking operation***

The parameters used for the ergonomic evaluation were WHR, OCR, EER, LCP, ODR, and BPDS. Any subject's WHR and OCR were computed during the cranking process for that person's physiological response. All subjects' WHR values were measured using a heart rate monitor (s810i, Polar Electro, Finland). A transmitter, receiver, and interface are all included in the WHR monitor, which allows data to be recorded every 5 seconds of operation. During the lab cranking operation, the WHR readings recorded for various loads in the computerised polar heart rate monitor were downloaded to the computer, and the values were obtained for further analysis. The computerised ambulatory measurement device, K4b2, which has a face mask through which the patient inhales and exhales, was used to assess the subject's oxygen consumption rate. During measurement, the portable instrument was hung on the test participant. It features telemetry recording capabilities that allow data to be recorded from a distance. Equation (1) was used to compute the oxygen consumption rate (Nag *et al.*, 1981).

$$OCR\ (l/min) = 0.0183\ HR - 1.28 \qquad ...(1)$$

***Energy cost of operation***

The oxygen consumption rate values for the 6th to 15th minute of the process in the laboratory were used to determine the EER for all the selected subjects under all operating conditions. Equation 2 (Nag *et al.*, 1980) was used to determine the energy expenditure rate for Indian subjects in each experimental trial.

$$EER = 20.88 \times O_2 \qquad ...(2)$$

where, EER = Energy expenditure rate, kJ/min;

$O_2$ = Oxygen consumption rate, l/min.

According to the energy consumption rate, the energy cost of work for selected operating situations was graded.

***Statistical analysis***

Experimental working heart rate and energy expenditure data of cranking operation for different subjects were collected and analyzed using full factorial experimental design. Data analysis was completed with the help of SPSS Ver. 20 (IBM). The effect of the load was analyzed with Analysis of Variance (ANOVA) with the General Linear Model (GLM) (Kumar *et al.*, 2018; Kumar *et al.*, 2020) for variation in heart rate and energy expenditure rate for selected subjects.

***Overall discomfort rating ODR analysis***

Overall discomfort rating is a 10-point psychophysical rating scale showing the discomfort in incremental order, where 0 means no discomfort and ten means extreme discomfort. A scale of 70 cm in length was fabricated, having 0 to 10 digits marked on it equidistantly. After completing each task, the subject was asked to indicate their overall discomfort level on the 10-point scale. All twelve subjects' overall discomfort scores for cranking force exertion were obtained with the adoption of the Corlett and Bishop (1976) technique.

**RESULTS AND DISCUSSION**

***Effect of cranking operation on subject's physiological cost***

The Polar heart rate monitor recorded the WHR during the cranking operation at 30 rpm, and the data were exported to the computer (Kumari *et al.*, 2022) with a suitable connection. The average working heart rate of the subjects during cranking operation at 30 rpm with 10, 30, 50 and 70 N load was obtained as 102, 108, 118 and 135 beats/min, respectively. The working heart rate values of the subjects during the cranking operation are presented for all the selected loads (Fig. 2). From Fig. 2, it is evident that the subject's heart rate value increases with an increase in applied load. The heart rate value also increases with effective working time duration. The findings of the results were according to the results obtained from (Kumari *et al.*, 2022). The heart rate values were found to vary between 70 to 150 beats/min for the assigned time duration.

**Limit of Continuous Performance (LCP)**

Work pulse (ΔHR) is the increase in heart rate over resting heart rate. ΔHR of all the selected subjects during the cranking operation was calculated. The average work pulse of the subjects during cranking operation at 30 rpm with 10, 30, 50 and 70 N load was obtained as 26, 32, 41 and 59 beats/min, respectively. Work pulse of the subjects with 10 and 30 N loads was found within the LCP (<40 beats/min) but not with 50 and 70 N loads (Fig. 3).

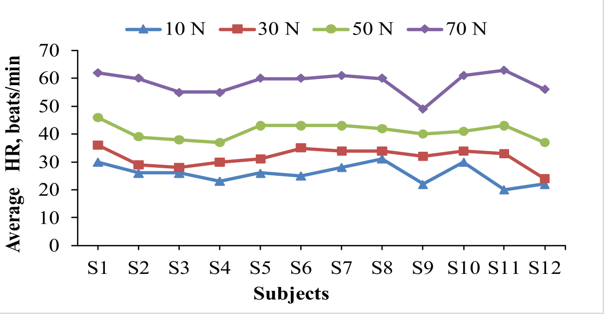


**Fig. 3: ΔHR values of all the subjects during cranking operation**

**Heart rat**

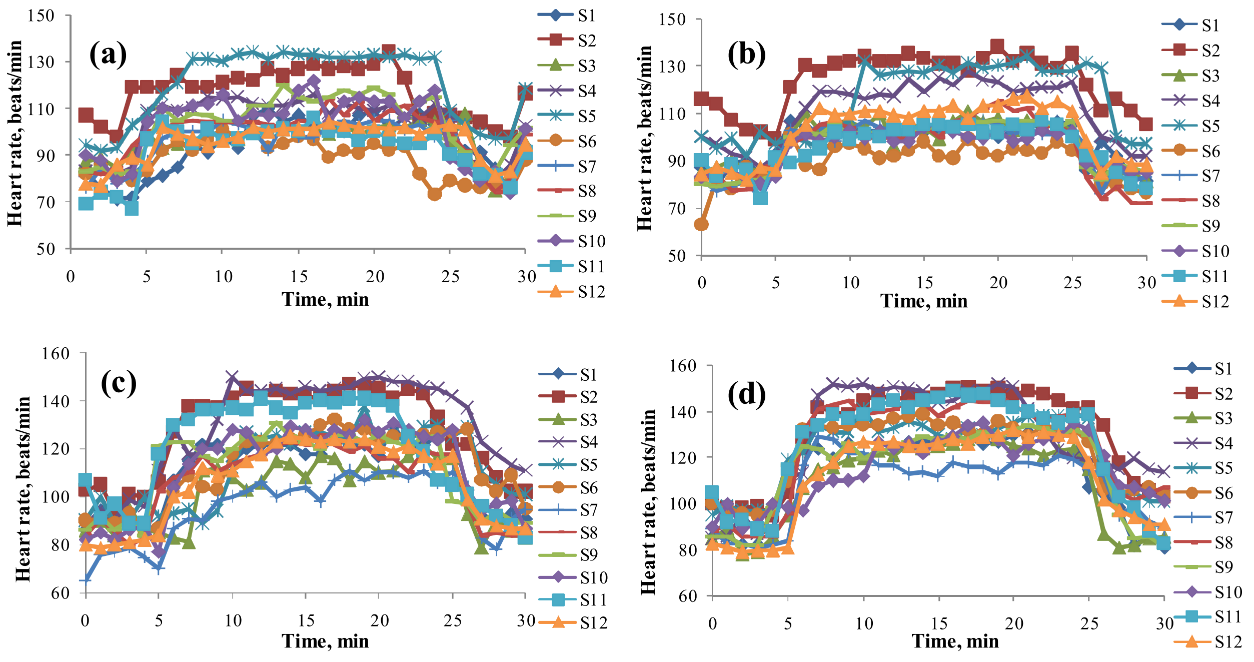


**Fig. 2: Working heart rate values of the subjects during cranking operation with (a) 10 N, (b) 30 N, (c) 50 N and (d) 70 N loads**

**Oxygen consumption rate (OCR)**

OCR is the amount of oxygen intake utilized by the body per minute. The amount of consumed OCR was calculated by using the working heart rate. The average OCR of the selected subjects with 10, 30, 50 and 70 N loads were obtained as 0.59, 0.70, 0.87 and 1.19 l/min, respectively. OCR of all the subjects during cranking operation is presented in Fig. 4.

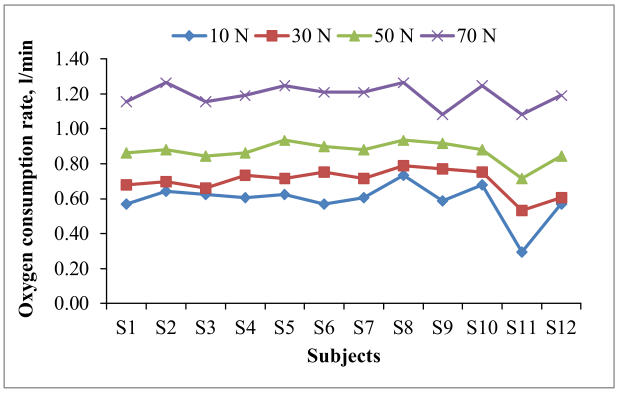


**Fig. 4: OCR values of all the subjects during cranking operation at different loads**

**Energy expenditure rate (EER)**

The EER during the operation was calculated by using OCR. The average EER of the subjects at 30 rpm with 10, 30, 50 and 70 N load was calculated as 12.34, 14.60, 18.17 and 24.86 kJ/min, respectively. EER of all the subjects is presented (Fig. 5).According to the classification of manual jobs based on energy expenditure during the operation, cranking operation with a 10 N load fell in the light category, whereas 30 and 50 N fell in the moderately heavy category, and 70 N fell under the heavy category.

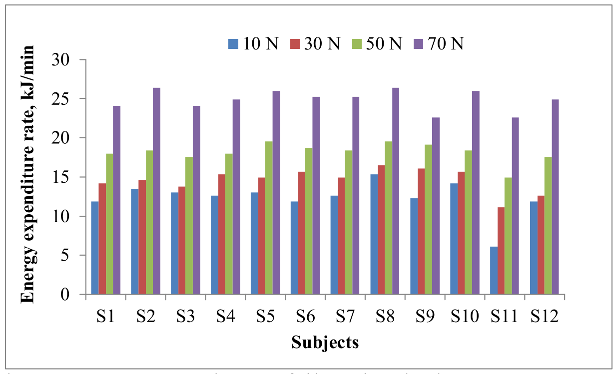


**Fig. 5: EER values of all the subjects during cranking operation at different loads**

***Statistical analysis of cranking***

ANOVA Tables show the effect of load on heart rate and energy expenditure rate at 95% confidence interval (Tables 2 and 3). The assessment concluded that the selected male subject's heart rate and energy expenditure rate differed significantly with respect to loads of different weights. The Duncan multiple range tests (Kumar and Pandey, 2016) were also conducted to see the effect of the mean values of WHR, OCR and EER with the applied loads (Table 4) and found that the mean value significantly varies from each other with an increment of applied load at 95%

**Table 2: Variation of average heart rate while cranking different loads**

| Source | Type III Sum of Squares | df | Mean Square | F-value |
|---|---|---|---|---|
| Corrected Model | 1224.250[a] | 3 | 408.083 | 306.063 |
| Intercept | 190764.083 | 1 | 190764.083 | 143073.063 |
| Load | 1224.250 | 3 | 408.083 | 306.063 |
| Error | 10.667 | 8 | 1.333 | |
| Total | 191999.000 | 12 | | |
| Corrected Total | 1234.917 | 11 | | |

R Squared = 0.987 (Adjusted R Squared = 0.983), df = degree of freedom, F-value: index of significance of the coefficient of determination

**Table 3: Variation of average energy expenditure while cranking different loads**

| Source | Type III Sum of Squares | df | Mean Square | F-value |
|---|---|---|---|---|
| Corrected Model | 178.740a | 3 | 59.580 | 306.071 |
| Intercept | 5521.445 | 1 | 5521.445 | 28364.423 |
| Load | 178.740 | 3 | 59.580 | 306.071 |
| Error | 1.557 | 8 | .195 | |
| Total | 5701.742 | 12 | | |
| Corrected Total | 180.298 | 11 | | |

R Squared = 0.987 (Adjusted R Squared = 0.983), df = degree of freedom, F-value: index of significance of the coefficient of determination confidence interval. The lower mean values of WHR, OCR, and EER were observed at the 10 N load applications. However, these values are maximum at 70 N force applications.

***Overall Discomfort Rating (ODR) and Body Part Discomfort Score (BPDS)***

All subjects' overall discomfort rating (ODR) for cranking force exertion at all loads was obtained. The ODR for cranking for all selected subjects are presented (Fig. 6). The subjects' mean value of ODR for 10 N was 3.1, for 30 N was 4.2, and for 50 N was 5.7. Maximum ODR was obtained with 70 N loads as 6.3. ODR during cranking operation with 10 N fell under more than light discomfort, 30 N and 50 N fell under moderate discomfort category, and 70 N fell under more than moderate discomfort category.

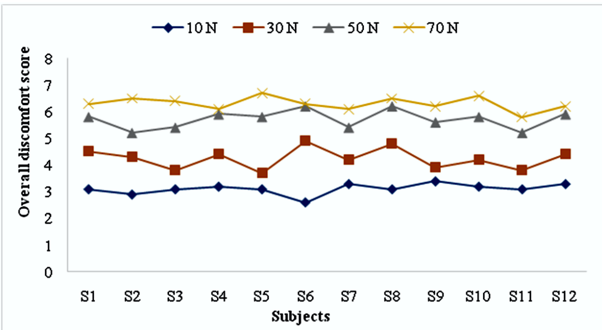


**Fig. 6: ODR values of all the subjects during cranking operation at different loads**

According to the Corlett and Bishop Technique (1976) regional discomfort scale, BPDS was calculated. BPDS for cranking operation of all the subjects were obtained in the range of 35.2 to 38.3. Maximum pain experienced by the subjects was in left and right shoulder, left and right arm, left and right wrist, left and right palm, left and right leg for all the subjects.

**Table 4: Duncan post hoc test for cranking operation under various loading conditions**

| Load (N) | WHR | OCR | EER |
|---|---|---|---|
| 10 | $102^{D}$ | $0.59^{D}$ | $12.34^{D}$ |
| 30 | $108^{C}$ | $0.70^{C}$ | $14.60^{C}$ |
| 50 | $118^{B}$ | $0.87^{B}$ | $18.17^{B}$ |
| 70 | $135^{A}$ | $1.19^{A}$ | $24.86^{A}$ |

Values in the same columns followed by different superscript letter (A-D) are significant.

## CONCLUSION

This study suggests a new design limit for manually operated cranking types of agricultural machinery based on gathered data. The cranking operation data is generated with complete attention to the agricultural worker's ergonomic, comfort, and safety factors to reduce labour drudgery and increase productivity. The investigation's findings supported the hypothesis that male subjects' heart rates varied significantly under various applied loads. The working heart rate, oxygen consumption rate and energy expenditure rate of selected subjects for cranking operations ranged from 102 to 135 beats/min, 0.59 to 1.19 l/min and 12.34 to 24.86 kJ/min, respectively, for all applied loads. According to the classification of a manual job based on the physiological response, the energy expenditure rate during cranking operation at 10 N loads fell into the light grade of work category. The 30 N and 50 N loads were classified as the moderate grade of work category, while 70 N were classified as heavy. The work pulse of the subjects was found to be within the LCP (40 beats/min) for10 and 30 N loads but not for loads of 50 and 70 N. Hence, these levels were not recommended. Overall discomfort rating of cranking operation was obtained in the range of 3.1 to 6.3 on the adopted 10-point scale, while body part discomfort scores (BPDS) for cranking operation of all the subjects were obtained in the range of 35.2 to 38.3. Any agricultural equipment should be designed within the 50 N loads to reduce workload and drudgery and thereby increase agricultural workers' productivity, comfort and safety.

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## REFERENCES

Aware, V. V., Chougule, S. M., Dabholkar, N. R. and Kadam, V. B. (2015). Field performance and ergonomic evaluation of manual operated cranking type rice transplanter. *Journal of the Indian Society of Coastal Agricultural Research,* 33(1): 46-51.

Ballinger, D. A., Rintala, D. H., and Hart, K. A. (2000). The relation of shoulder pain and range-of-motion problems to functional limitations, disability, and perceived health of men with spinal cord injury: a multifaceted longitudinal study. *Archives of Physical Medicine and Rehabilitation*, 81(12): 1575-1581.

Capodaglio, P. and Bazzini, G. (1996). Predicting endurance limits in arm cranking exercise with a subjectively based method. *Ergonomics*, 39(7): 924-932.

Corlett, E. N. and Bishop, R. P. (1976). A technique for assessing postural discomfort. *Ergonomics,* 19: 175-182.

Dyson-Hudson, T. A., Sisto, S. A., Bond, Q., Emmons, R., and Kirshblum, S. C. (2007). Arm crank ergometry and shoulder pain in persons with spinal cord injury. *Archives of Physical Medicine and Rehabilitation*, 88(12): 1727-1729.

Frymoyer, J. W., Pope, M. H., Costanza, M. C., Rosen, J. C., Goggin, J. E. and Wilder, D. G. (1980). Epidemiologic studies of low-back pain. *Spine*, 5(5): 419-423. (DOI: 10.1097/00007632-198009000-00005)

Gite, L.P. ed. (2009). Anthropometric and strength data of Indian agricultural workers for farm equipment design. Bhopal, Central Institute of Agricultural Engineering.

Gite, L.P. and Singh, G. (1997). Ergonomics in agricultural and allied activities in India. Central Institute of Agricultural Engineering, Bhopal.

Grandjean, E. (1980). Fitting the task to the man – An ergonomic approach. London: Taylor & Francis Co.

Kumar, A., Singh, J. K. and Singh, C. (2010). Ergonomic assessment of a manual fodder cutter. *Journal of Agricultural Engineering,* 47(4): 1-9.

Kumar, S. and Pandey, K. P. (2016). Behaviour of deflection and contact characteristics of agricultural tyre with zero sinkage. In precision farming and resource management. Excel publishers, New Delhi, India, 1: 46-53.

Kumar, S., Pandey, K. P., Kumar, R. and Kumar, A. A. (2018). Effect of ballasting on performance characteristics of bias and radial ply tyres with zero sinkage. *Measurement*, 121: 218-224. (https://doi.org/10.1016/j.measurement.2018.02.043)

Kumari, S., Tewari, V. K. and Kumar, S. (2022). Assessment of physiological characteristics and effect of load on agricultural workers during push–pull operation under laboratory conditions. *Materials Today: Proceedings,* (https://doi.org/10.1016/j.matpr.2022.06.007).

Luime, J. J., Koes, B. W., Hendriksen, I. J. M., Burdorf, A., Verhagen, A. P., Miedema, H. S., and Verhaar, J. A. N. (2004). Prevalence and incidence of shoulder pain in the general population; a systematic review. *Scandinavian Journal of Rheumatology*, 33(2): 73-81.

Nag, P. K. (1981). Predicting maximal oxygen uptake of workers engaged in agricultural tasks. *Journal of Human Ergology*, 10(1): 25-33. ( https://doi.org/10.11183/jhe1972.10.25).

Nag, P. K., Panikar, J. T., Malvankar, M. G., Pradhan, C. K. and Chatterjee, S. K. (1982). Performance evaluation of lower extremity disabled people with reference to hand-cranked tricycle propulsion. *Applied Ergonomics,* 13(3): 171-176.

Nag, P. K., Sebastian, N. C. and Malvanker, M. G. (1980). Occupational workload of Indian Agricultural workers. *Ergonomics,* 23: 91-102.

Kumar. N., Kumar, S., Kumar, R. and Pandey, K. P. (2020). Dynamic behaviour of high-powered agricultural tractor for haulage operation. *Pantnagar Journal of Research*, 18(1): 69-75.

Potdar, R. R., Ram, R., Kumar, A., Singh, J. K. and Mani. I. (2011). Ergonomic evaluation of rotary power input by hand and leg muscles to operate farm equipment. *Journal of Agricultural Engineering,* 48(3):8-16.

Singh, S. P., Singh, S. and Singh, P. (2012). Ergonomics in developing hand operated maize dehusker–sheller for farm women. *Applied Ergonomics*, 43(4): 792-798.

Tiwari, P. S., Pandey, M. M., Gite, L. P. and Shrivastava, A. K. (2014). An ergonomic intervention in operation of a rotary maize sheller. *Indian Journal of Agricultural Sciences,* 84(7): 791-5.

World health organization (https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index)

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