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Ergonomic intervention in sugarcane harvesting knives

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Ergonomic evaluation of farm tools is necessary to improve the fit between the physical demands of the tools and the worker who perform the work. In spite of improved farm mechnization, the use of the hand tools is inevitable in certain agricultural operations like sugarcane harvesting. Commonly used and high energy demanding tools like sugarcane harvesting knives of various models available in India were selected to assess the ergonomic suitablity. Ten individuals were selected for the investigation based on the age and fitness. They were screened for normal health through medical investigations. Four models of sugarcane harvesting knives were selected for ergonomical evlauation. The parameters used for the ergonomical evaluation of screened sugarcane harvesting knives include heart rate and oxygen consumption rate, energy cost of operation, acceptable work load, over all discomfort rate and body part discomfort score. The maximum aerobic capacity of the selected ten individuals varied from 1.84 to 2.19 L min^{-1} for sugarcane harvesting. The heart rate and oxygen consumption rate of the sugarcane knives varied from 132.55 to 138 beats min^{-1} and 1.171 to 1.253 L min^{-1}, respectively. The energy cost of sugarcane harvesting knives, varied from 24.45 to 26.16 kJ min^{-1} respectively. The values of percent maximum aerobic capacity (VO_2 maximum) and work pulse for sugarcane harvesting knives were much higher than that of the acceptable workload (AWL), limits of 35%. Based on the analysis of results, the sugar cane harvesting knife (H1) ranked as I in terms of minimum value of heat rate (132.55 beats min^{-1}), energy cost of work (24.45 KJ min^{-1}), acceptable work load (58.14%), over all discomfort rate (moderate discomfort) and Body part discomfort score (29.39) when compared with other three models (H2, H3 and H4) of sugarcane harvesting knives.

Key words: Sugarcane harvesting, ergonomics, heart rate, oxygen consumption.

INTRODUCTION

Harvesting of sugarcane crop is an important agricultural operation in which, it is estimated that less than 20% of the world's more than 100 million tonnes of sugarcane is harvested mechanically (Anonymous, 2005). Harvesting systems vary widely and the choice of one system over another will depend on labour availability, labour cost, topography and climatic conditions. Sugarcane harvesting is highly labour intensive operation requiring around 1200 labour hour per heactare (Anonymous, 2005). For most of the sugarcane crops in India harvesting is done manually using locally made small hand tools such as knives. The farmers generally use old designs made of iron for harvesting sugarcane. The sugarcane harvesting operation involves the unit operations including, cutting the sugarcane, detrashing the cane, detopping and carrying to farm shed for manufacturing of jaggery or loading the bunch of sugarcane in truck for transport to sugar mills.

Agricultural ergonomics emerges as a potential discipline for whole ranging application in farming methods and practices. This discipline specifies application of those work sciences relating human performance to the improvement of work system in farming activity. It encompasses the persons, the jobs, the tools

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and equipment, the work place and space, and the working environment. Most designers of agricultural equipment concentrate to improve efficiency and durability, but none seem to give importance to the operators' comfort. Hence there is an urgent need to critically analyse these agricultural tools/equipment for their ergonomics in order to improve man-machine system efficiency without sacrificing performance. This would greatly help the researchers to appropriately design simple and labour effective gadgets considering ergonomic requirements. In view of the sugarcane harvesting operation, it is desirable to ergonomically evaluate the available sugarcane harvesting knives to assess their suitability for farm workers for reduced drudgery and adequate comfort with the following specific objectives:

i. To measure the physiological cost (Heart rate and Oygen consumption rate) of the individuals while performing sugarcane harvesting operation with selected knives.
ii. To classify the workload in terms of energy cost of performing these operations.
iii. To assess the overall discomfort and body part discomfort rating of the subjects in the operation of selected sugarcane harvesting knives.

Srivastava et al. (1962) investigated the energy requirements, harvest rate and efficiency of grain harvesting equipment and concluded that there was a difference in the energy expenditure of different persons using the same harvesting equipment under similar condition. Sanders and McCormick (1993) stated that the linear relationship between heart rate and oxygen consumption is different for different people. So they suggested calibration of each person to determine the relationship between heart rate and oxygen consumption. They reported that heart rate is the best used as a predictor of oxygen consumption when moderate to heavy work is performed. They also stated that heart rate continuously sampled over a work day or task, is useful as a general indicator of physiological stress without reference to oxygen consumption or energy expenditure.

Kroemer et al. (1997) stated that heart rate and oxygen consumption have a linear relationship. They found that the relationship may change within one person with training, and it differs from individual to another. They inferred that heart rate measurements could be substituted for measurement of metabolic processes, particularly for oxygen consumption, since it could be performed easily. Bimla et al. (2002) investigated the efficiency of sickles in wheat harvesting. They found that the average heart rate was 110 and 107 to 109 beats min^{-1} for existing and improved sickles respectively and the corresponding average energy expenditure was 9.6 and 8.3 to 9.5 kJ min^{-1}. Maximal oxygen uptake, heart rate and muscle strength decreases significantly with old age (Astrand et al., 1965; Astrand and Rodahl, 1986).

The maximum strength or power can be expected from the age group of 25 to 35 years (Grandjean, 1982; Gite and Singh, 1997; Umrikar et al., 2004). Maximum muscle strength and at the same time the cross-sectional area of muscle is also greatest for this age group (Mc Ardle et al., 1994; Nigg and Herzog, 1999).

Other studies have researched the effect of different cane knives on performance. A study by de L Smit et al. (2001) compared short handled and long handled curved knives, and found the only difference in output to be the cutters' perception of exertion − indicating that the choice of knife and its usefulness depends on the preferences of the cane cutter. Nonetheless, other studies (Brooks, 1983) found some productivity enhancement with modified knife types.

MATERIALS AND METHODS

Sugarcane harvesting knives used in different regions of India procured and selected for ergonomical evaluations are shown in Figure 1 and Table 1. Selection of individuals plays a vital role in conducting the ergonomic investigations. The subject should be physically and medically fit to undergo the trials (Seidel et al., 1980). There should not be any major illness and handicaps and also they should be a true representative of the user population in operation of the selected sugarcane harvesting knives. Age and medical fitness is the main criteria for the selection of subjects. The medical and bio- clinical investigations like Electro Cardio Graph (ECG), blood pressure and bio-clinical analysis were conducted to assess the medical fitness of selected ten individuals participated in the investigation. Hence from the available workers, ten male workers in the age group 25 to 35 years were chosen considering their experience in the operation of the selected sugarcane harvesting knives. The characteristics of individuals are furnished in Table 2. A preliminary study was conducted with the selected 10 individuals for screening the selected ten models of knives. The criteria used for screening include: Over all discomfort rate (ODR) and body part discomfort score (BPDS), field capacity; subjective feedback, configuration similarity and versatility.

Ergonomical evaluation of screened sugarcane harvesting knives

Ergonomical evaluation was conducted with the screened sugarcane harvesting knives for assessing their suitability with the ten selected individuals. The evaluation was carried out in terms of heart rate and oxygen consumption rate, energy cost of operation, acceptable work load (AWL), over all discomfort rating (ODR) and body part discomfort score (BPDS).

Heart rate and oxygen consumption

Heart rate and oxygen consumption rate are the pertinent parameters for assessing the human energy required for performing various types of operation (Curteon, 1947). All the ten individuals were calibrated in the laboratory condition by indirect assessment of oxygen uptake. Oxygen consumption was measured by using the computerized ambulatory metabolic measurement system (Metamax-II) while running on the computerized treadmill (Viasys LE 200CE model). The corresponding heart rate was recorded using Polar Vantage NV computerized heart rate monitor (S 810i) at the submaximal loads. The maximum heart rate of all the selected individuals was computed using the equation proposed by

Figure 1. Different sugarcane harvesting knives selected for ergonomical evaluation.

Table 1. Specifications of ten models of sugarcane harvesting knives.

Model No.	Weight (g)	Thickness (mm)	Material of the blade	Diameter of the hand grip (mm)	Thickness of the cutting edge (mm)	Effective cutting length of the blade (mm)	Concavity (mm)	Material of the handle	Over all dimensions, L × B (mm)
01	550	4	Mild steel	32	1.02	160	58	Wood	347 × 160
02	550	4	Mild steel	31	1.02	160	58	Wood	357 × 150
03	600	4	Mild steel	36	1.02	203	40	Wood	380 × 150
04	550	4	Mild steel	36	1.02	133	86	Wood	375 × 160
05	450	4	Mild steel	33	1.02	180	34	Bamboo stick	357 × 98
06	700	6	Mild steel	34	1.02	220	-	Wood	413 × 74
07	500	3	Mild steel	34	1.02	155	49	Wood	380 × 122
08	500	1.5	Mild steel	168 × 62 × 20	1.02	225	67	Plastic	494 × 85
09	500	1.5	Mild steel	168 × 62 × 20	1.02	225	67	Plastic	494 × 85
010	400	1,5	Mild steel	155 × 60 × 22	1.02	215	-	Plastic	505 × 100

Astrand (1960) and the arrived values of maximum aerobic capacity (VO_2 maximum) for all the individuals. Because of the advantages of the indirect assessment of oxygen uptake, during the operation of each of the selected knives, only the heart rate of the subject performing the task was noted. The procedure adopted for each operation is explained subsequently.

Energy cost of operation

The recorded heart rate values from the computerized heart rate monitor were transferred to the computer through the interface in all the above cases. From the down loaded data, the values of heart rate at resting level and 6th to 15th minute of operation were taken for calculating the physiological responses of the subjects (Tewari and Gite, 1998). The heart rate increases rapidly in the beginning of an exercise and reaches a steady state by the end of sixth minute (Davies and Harris 1964). The stabilized values of heart rate for each subject from 6th to 15th minute of operation were used to calculate the mean value for all the selected sugarcane harvesting knives.

Table 2. Characteristics of selected individuals for sugarcane harvesting.

S/N	Individuals	Age (Year)	Weight (kg)	Height (cm)	Experience (Year)
1	I	25	57	157	> 5
2	II	26	61	159	> 5
3	III	29	53	161	> 5
4	IV	27	65	158	> 5
5	V	24	58	153	> 5
6	VI	32	54	164	> 5
7	VII	31	62	163	> 5
8	VIII	29	58	159	> 5
9	IX	28	64	156	> 5
10	X	26	49	156	> 5

From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate ($V0_2$) of the subjects for all the screened sugarcane harvesting knives were predicted from the calibration chart of the each subject. The energy costs of operation of the screened sugarcane harvesting knives were computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen as 20.88 kJ l^{-1} (Nag et al., 1980) for all the individuals. The values of heart rate, oxygen consumption and the energy expenditure for all the subjects were averaged to get the mean values for all the screened sugarcane harvesting knives.

Grading energy cost of work

Measured physiological demands are evaluated against various criteria to determine whether the physical demand of a certain task is excessive, and whether the worker performing the task may suffer from physical fatigue. The energy cost of individuals for screened sugarcane harvesting operation thus obtained was graded as per tentative classification of strains in different types of jobs according to the young Indian male workers given in ICMR report (Sen, 1969).

Acceptable workload (AWL)

During any physical activity, there is increase in physiological parameters depending upon the workload, and the maximum values, which could be attained in normal healthy individuals, will be up to VO_2 max. However at this extreme workload, a person can work only for a few seconds. The acceptable workload (AWL) for Indian workers was the work consuming 35% of VO_2 max (Saha et al., 1979). To ascertain whether the operation of all the screened sugarcane harvesting knives is within the acceptable workload (AWL), the VO_2 maximum for each treatment was computed and recorded. The acceptable workloads for extended periods as 33% of maximal aerobic capacity for an 8-hour shift and 28% for 12-hour sift (NIOSH, 1981). Kodak (1986) later confirmed this.

Overall discomfort rating (ODR)

For the assessment of overall discomfort rating a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used which is an adoption of Corlett and Bishop (1976) technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly. A moveable pointer was provided to indicate the rating. At the end of each trial subjects was asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the ten individuals are added and averaged to get the mean rating.

Body part discomfort score (BPDS)

To measure localized discomfort, Corlett and Bishop (1976) technique was used. In this technique the subject's body is divided into 27 regions. A body mapping similar to that of body mapping was made with thermocoal to have a real and meaningful rating of the perceived exertion of the subject. The subject was asked to mention all body parts with discomfort, starting with the worst, the second worst and so on until all parts have been mentioned (Lusted et al., 1994). The subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on (Legg and Mohanty, 1985).

Field evaluation of screened sugarcane harvesting knives

The experiment was conducted in sugarcane fields located at sarvanampatti village of Tamil Nadu. Field experiments were conducted with selected sugarcane harvesting knives during the month of February and March 2006. The temperature and relative humidity varied from 32 to 36°C and 28 to 64%, respectively during the period of evaluation. The field selected for trail was planted with CO 86032 variety of sugarcane. The individuals were given information about the experimental requirements so as to enlist their full cooperation. The trail was conducted between 7.30 AM to 5.00 PM. They were given rest for 30 min before starting the trial. After rest period of half an hour, individuals performed the harvesting operation shown in Figure 2. Trials with duration of 20 min were conducted for all ten individuals. The data for heart rate was recorded using computerized heart rate monitor. The same procedure was repeated for all the individuals and also for screened harvesting knives with three replications.

RESULTS AND DISCUSSION

Ten models of sugarcane harvesting knives are screened in to four for ergonomic evaluation according to the feedback of the sugarcane cutters, BPDS, ODR values and field capacity were presented in Table 3. The sugarcane cutters are mainly preferred to use the Gobichettypalayam model (01), Dharmapuri model (02), Cuddalore models (03 and 04) and Kallakuruchi model (07). Model 02 (Dharmapuri model) is selected from the

Figure 2. View of sugarcane harvesting knife in operation.

Table 3. Criteria used for screening of harvesting knives.

S/N	Sugarcane harvesting knives	Field capacity (Ha h^{-1})	ODR values	BPDS values
1	Gobichettipalayam model 01	0.00201	5.51	30.10
2	Dharmapuri model 02*	0.00209	5.67	29.39
3	Cuddalore model 03*	0.00173	6.04	29.65
4	Cuddalore model 04*	0.00177	6.19	32.92
5	Melalathur model 05	0.00129	5.82	29.37
6	Coimbatore model 06	0.00135	6.95	46.32
7	Kallakuruchi model 07*	0.00185	5.71	28.21
8	Pune model (right) 08	0.00101	6.17	36.02
9	Pune model (left) 09	0.00100	6.29	37.13
10	Pune model 10	0.00110	6.38	31.41

*Screened models of knives for ergonomical evaluation.

two models (01 and 02) because the both the models have the same similarities. The following four harvesting knives (H1, H2, H3 and H4) were screened for ergonomic evaluation owing to their suitability, increased comfort, user friendly, versatility and field capacity. The screened harvesting knives (H1, H2, H3 and H4) are shown in Figure 3.

The physiological response of the individuals with respect to time for the operation of the four screened sugarcane harvesting knives (H1, H2, and H3 and H4) is depicted in Figures 4 and 5. From the graph it is observed that the heart rate of the individuals increased steeply from the beginning of the operation and stabilized in the range of 120 to 145 beats min^{-1} after 6^{th} minute of operation. The readings for the individuals from 6th to 15th minute were considered for the calculation of the heart beat rate for screened models of sugarcane harvesting knives. It is also observed that there existed a difference in the heart rate among the subjects using the same tools under the same conditions due to difference in subject's age, weight and stature. The mean values of heart rate of all the selected individuals and the corresponding oxygen consumption value are furnished in Table 4.

The mean value of energy expenditure of subjects for operation with sugarcane harvesting knives varied from 24.45 to 26.16 kJ min^{-1}. The values are in close agreement with the value of 24.58 kJ min^{-1} reported by Yadav and Srivastava (1984) for sugarcane harvesting knives. Performing the sugarcane harvesting operation in bending

Figure 3. Screened sugarcane harvesting knives.

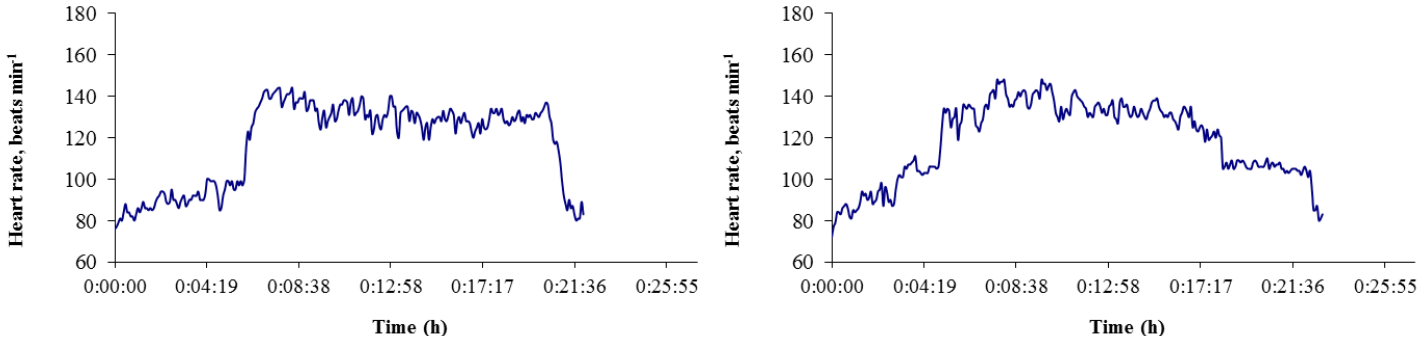

Figure 4. Heart rate response of the individual during the operation of sugarcane harvesting with H1 and H2 model.

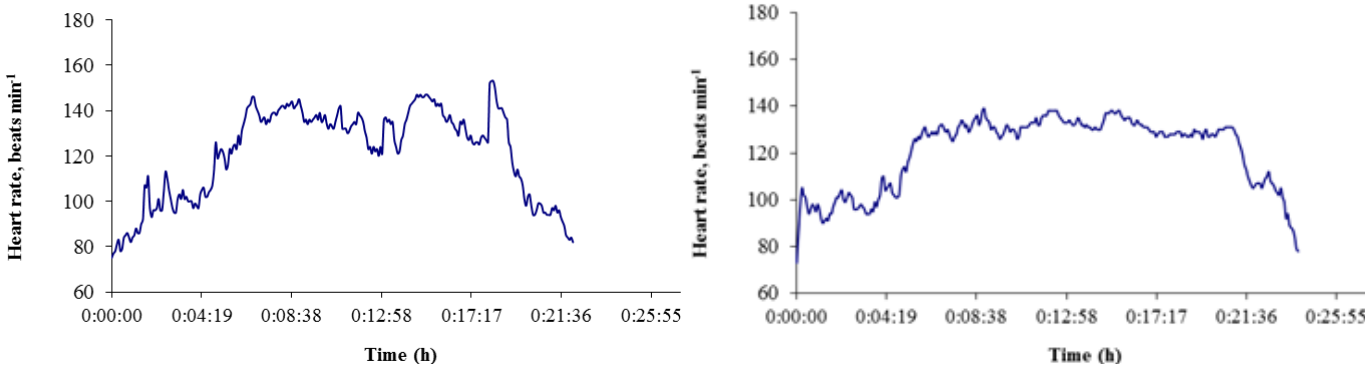

Figure 5. Heart rate response of the individuals during the operation of sugarcane harvesting with H3 and H4 model.

posture, holding the sugarcane crop in one hand and forcing the knives in sideward for harvesting the cane, these operations are graded as “heavy". The order of ranking of the harvesting knives based on energy cost was H1, H4, H3 and H2. The mean values of oxygen consumption rate (OCR) in terms of percent VO_2 max for screened sugarcane harvesting knives were 58.14 to 62.21%, respectively. These values were much higher than that of the AWL limit of 35% of VO_2 max indicating that all the screened sugarcane harvesting knives could not be operated continuously for 8 h without frequent rest-pauses.

From the rating of perceived exertion of the subjects, the ODR scale for screened sugarcane harvesting knives was “moderate discomfort” for models H1, H3 and H4 and more than moderate for model H2. Based on the

Table 4. Average physiological responses of individuals for operation of screened sugarcane harvesting knives.

Tools	Heart rate (beats min^{-1})	VO_2 (L min^{-1})	Energy expenditure (kJ min^{-1})	Energy grade of work	Rank
H1	132.55	1.171	24.45	Heavy	I
H2	137.41	1.253	26.16	Heavy	IV
H3	138.00	1.252	26.14	Heavy	III
H4	133.17	1.187	24.78	Heavy	II

Table 5. Average body part discomfort score for screened knives.

Screened knives	Body part experiencing pain	Score
H1	Moderate pain in shoulders, palms, elbow, wrist, mid back	29.39
H2	Moderate pain in shoulders, palms, elbow, wrist, mid back	31.65
H3	Moderate pain in shoulders, palms, elbow, wrist, mid back	32.92
H4	Moderate pain in shoulders, palms, elbow, wrist, mid back	28.21

Corlett and Bishop (1976) regional discomfort scale, the mean values of body part discomfort score for all the screened sugarcane harvesting knives were presented in Table 5.

The majority of discomfort experienced by the workers was in the right shoulders, palm, mid back and right elbow for all the individuals. This discomfort experienced by the individual's subjects was mainly due to the frequent sideward force given for cutting the sugarcane, a rough handle grip and weight of the knife.

Conclusion

Based on the analysis of the results the following conclusions are drawn.The selected ten individuals were calibrated in the laboratory by indirect assessment of oxygen uptake. The relation ship between the heart rate and the oxygen consumption was found to be linear for all the subjects. The maximum aerobic capacity of the selected ten subjects for sugarcane harvesting knives varied from 1.84 to 2.19 l min^{-1}. For sugarcane harvesting operation with H1, H2, H3 and H4 knives, the mean value of heart rate was 132.55, 137.41, 138 and 133.17 beats min^{-1} respectively and the corresponding oxygen consumption value was 1.171, 1.253, 1.252 and 1.187 L min^{-1}, respectively. From the mean value of oxygen consumption, the energy expenditure for screened sugarcane harvesting knives H1, H2, H3, H4 was computed as 24.45, 26.16, 26.14 and 24.78 kJ min^{-1}, respectively. The operation was graded as "heavy". The energy expenditure for screened sugarcane harvesting operation indicated that the energy cost of work was the highest for H1 followed by H4, H3 and H2. The oxygen consumption rate in terms of VO2 max for screened sugarcane harvesting knives H1, H2, H3 and H4 varied from 58.14 to 62.21%. The minimum over all discomfort rate value of 5.67 for sugarcane harvesting knives (H1) indicated that model H1 exerted relatively lesser fatigue on the operator when compared with other three models. The majority of discomfort experienced by the workers in the operation of sugarcane harvesting H1, H2, H3, and H4 was in the right shoulder, wrist, elbow and mid back due to more weight and frequent sideward force given for cutting the sugarcane, a rough handle grip of the knife.

RECOMMENDATIONS

From the results, sugarcane harvesting knife (H1) is registered the lowest value of ergonomical evaluational parametersis taken and necessary ergonomics refinements like redesigning the knife (weight may be reduced by replacing the carbon steel instead of mild steel and width may also be reduced, a fine gripness may be provided in the handle of knife to reduce the palm itching, blister or welts) should be carried out for enhancing the comfort of the operator without jeoparadizing the efficiecy of the sugarcane harvesting knife.

REFERENCES

Anonymous (2005). Cotton crop improvement. Crop Production guide. Published by Department of Agriculture, Government of Tamil Nadu, Chennai.

Astrand I (1960). Aerobic work capacity in men and women. Acta Physiologica Scandinavica 4:1691-1692.

Astrand PO, Ekblon B, Messin R, Stallin B, Stenberg J (1965). Intra-Arterial blood pressure during exercise with different muscle group. J. Appl. Physiol. 20:253-256.

Astrand PO, Rodahl K (1986). A Textbook of work physiology. New York, Mc. Graw Hill.

Bimla S, Gandhi, Dilbaghi M (2002). Efficiency testing of sickles in wheat harvesting. An ergonomic study. Department of Family Resource Management, College of Home Science, CCSHAU, Hisar.

Brooks RC (1983). Improving cane cutters' productivity. Proc. South Afr. Sug. Technologist Assoc. 57:165-166.
Corlett EN, Bishop RP (1976). A technique for assessing postural discomfort. Ergonomics 19:175-182.
Curteon TK (1947). Physical fitness appraisal and guidance. The C.V.Mosby Co., St Louis.
Davies CTM, Harris EA (1964). Heart rate during transition from rest to exercise in relation to exercise tolerance. Journal of applied Physiology. 19(5):857-862.
de L Smit M, Coetsee MF, Davies SHE (2001). Energy expenditure and economy of movement of sugarcane cutters in burnt and green cane. Proc South Afr. Sug. Technologist Assoc. 75:46-50.
Gite LP, Singh G (1997). Ergonomics in agricultural and allied activities in India. Central Institute of Agricultural Engineering, Bhopal.
Grandjean E (1982). Fitting the task to the man – An ergonomic approach. Taylor and Francis Ltd., London.
Kodak, Eastman Company (1986). Ergonomic design for people at work, vol.2. New York: Van Nostrand Reinhold.
Kroemer KHE, Kroemer HJ, Kroemer KE (1997). Engineering physiology. Van Nostrand Reinhold. New York. pp. 193-228.
Legg SJ, Mahanty A (1985). Comparison of five modes of carrying a load close to the trunk. Ergonomics 28(12):1653-1660.
Lusted M, Healey S, Mandryk JA (1994). Evaluation of the seating of Qantas flight deck crew. Appl. Ergonomics 25:275-282.
Mc Ardle DE, Katch FI, Katch VL (1994). Essentials of exercise physiology. Lea &Febiger, A waverly company, Philadelphia: p.508.
Nag PK, Sebastian NC, Malvanker MG (1980). Occupational workload of Indian Agricultural workers, Ergonomics 23(2):91-102.
Nigg BM, Herzog W (1999). Bio mechanics of the musculo skeletal system. 2nd Edn., John Wiley and Sons, New York. p. 156.
NIOSH (National Institute for Occupational Safety and Health) (1981). Work practices guide for manual lifting, DHHS/NIOSH Publication #81-122. Washington D.C: Government Printing Office.
Saha PN, Datta SR, Banerjee PK, Narayane G (1979). An acceptable workload from a modified scale of perceived exertion, Ergonomics 37:485-491.
Sanders, McCormic (1993). Human Factors in Engineering and Design. Seventh Ed., McGraw Hill, Inc, New York.
Seidel H, Bastek R, Brauer D, Buchholz CH, Meister A, Metz AM,Rothe R (1980). On human response to prolonged repeated whole body vibration. Ergonomics 23(30):191-211.
Sen RN (1969). Tentative classification of strains in different types of jobs according to the physiological responses of young Indian workers in comfortable climates. ICMR report, Indian Council of Medical Research, New Delhi.
Srivastava K, Johnson AC, Zahradnik JW (1962). Energy requirements, harvest rates and efficiency compared for several hand grain harvesting implements. Paper presented at the Annual Meeting of ASAE at May Flower Hotel, Washington, D.C.
Tewari PS, Gite LP (1998). Human energy expenditure during power tiller operation. Paper presented at XXXIII annual convention of ISAE held at CIAE, Bhopal, Sept. pp. 21-23.
Umrikar SH, Zend JP, Upadhyay RK, Murali D (2004). Health status of farm women. Paper presented at National Conference on Humanizing Work and Work Environment, National Institute of Industrial Engineering, Mumbai, April. pp. 22-24.
Yadav RNS, Srivastava NSL (1984). Sugarcane harvesting knives used in India. The Indian Sugar Crops J. July-September. pp. 5-8.