International Journal of Education and Science Research Review
Volume-1, Issue-2 April- 2014 ISSN 2348-6457

ERGONOMIC STRESSORS AND METABOLIC ACIDOSIS IN MANUALLY OPERATED OCCUPATIONS

Amit Pratap Singh
Department of Chemistry,
Indian Institute of Technology,
Roorkee, Uttarakhand

Sucheta Singh
Directorate of Extension Education,
G.B. Pant University of Agriculture & Technology
Pantnagar, Uttarakhand

Manoj Kumar
Department of Chemistry
N.R.E.C. P.G. College
Khurja(Bulandshahar)

Abstract-
Women do have an access to new agricultural technologies that could have save their tremendous amount of time and back breaking labour. Therefore, the present study was carried out with a sample of women having average weight of 47.39 kg, average height of 152.2 cm, BMI of 20.34 kg/m^2, eye height of 140.2 cm, shoulder height of 126.2 cm. standing elbow height of 98.91 cm, standing knuckle height of 68.91 cm, 26.32 % women with good physical fitness on step stool test, average resting heart rate of 76 beats/min. and average aerobic capacity of 2.09 litre/min.. The study focuses on ergonomic stressors and metabolic acidosis of the three different types of sickle used by the women farmers for harvesting the crops in summer season. The ergonomic stressors showed a maximum change in 24.16 % grip strength, 125.19 % working heart rate and 2025 litre/min. with Type A sickle. Whereas, energy expenditure as equally found a change of 11.27 % in Type A and Type C sickle. The biochemical analysis of lactic acid formation was found as a causal factor for the fatigue of 59.48 % in type A sickle, 29.96 % in type B sickle and 48.40 % in type C sickle.

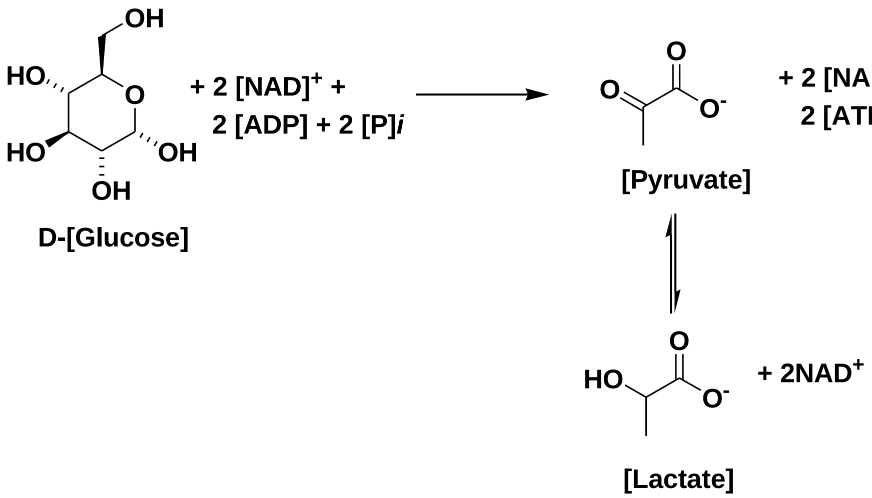
Keywords- Ergonomics, harvesting, metabolic acidosis.

I. INTRODUCTION

Many farmers in India and other developing countries endeavor primarily to feed their families from one harvest to the next. In Indian agriculture, along with men workers women also play a significant and crucial role in agricultural operations, including different crop productions activities, post-harvest activities, etc. [1].

While being an integral and crucial part of the agricultural system, women do have an access to new agricultural technologies that could have save their tremendous amount of time and back breaking labour. The main household concerns include: (a) food production- securing the nutritional status of the household and its individual members: (b) household needs- the ability of the household to procure additional food and other necessities that are required to support a basic existence, possibly through income from outside agriculture and (c) social arrangements- to enhance people's capabilities to secure their livelihoods [2].

Particular attention must be paid to the needs of women and other marginalized groups, who, in most small holder farming systems, devote many more hours than men to agricultural production and are more often involved in hand labour [3]. Studies have pointed out that farm activity those are time and labour intensive, monotonous, repetitive and more drudgery prone. Since all these activities are done manually, they cause considerable physical and mental fatigue aggressed by hot and humid environment and other health problems [4]. Simple devices (originally sticks and stones) used to increase labour productivity. Hand tools are still important even in highly mechanized agriculture [5]. During the manual work when the rate of demand for energy is high, D-[Glucose] is broken down into pyruvate, and lactate. The free energy released in this process is used to form the high-energy compounds ATP (adenosine triphosphate) and NADH (reduced nicotinamide adenine dinucleotide) as shown in Scheme-1.



Scheme-1: Metabolic pathway for the generation of pyruvate and lactate from D-[Glucose]

The production of lactate during the gluconeogenesis is a beneficial process because it regenerates NAD^+, which is used up in oxidation of 3-phosphoglyceraldehyde during creation of pyruvate from glucose, and this ensures that energy production is maintained and physical work can continue. But, during intense agricultural operations, the respiratory chain cannot keep up with the amount of hydrogen atoms that join to form NADH, and cannot regenerate NAD^+ quickly enough [6], [7].

Therefore, the present paper envisages the study on ergonomic stressors and metabolic acidosis of the three different types of sickle used by the women farmers for harvesting the crops in summer season.

II. MATERIALS AND METHODS

In this study the human energy was measured by the open circuit indirect method using the heart rate as the measuring index and grip strength. The heart rates and grip strength of the subjects were measured at 3 different types of sickles viz. traditional type used by the farmers (A), *naveen* sickle (B) and improved sickle-*Pauri* (C) used during the harvesting of wheat. A stop watch to count 10 heart beats immediately after load carrying activity was used. This was representative of the heart rate during the work since the heart rate remains constant for some seconds after the cessation of a task [8], [9], [10]. The measurements were taken in the field conditions same as the harvesting operation is performed by the women in seasonal activities. The energy expenditure and total cardiac cost of work (TCCW) were calculated using the following standard formulae:

Energy Expenditure (kJ./min.)= [0.159 × Average Working Heart Rate (beats/min.)] – 8.72

Total Cardiac Cost (Beats) = [Average Working Heart Rate – Average Resting Heart Rate (beats/min.)] × Duration (min.)

Reasonably complete data were coded and entered into a database. All of the entries were manually checked to verify the accuracy of data entry. Descriptive statistics (e.g. mean, percent) were used to describe the sample. Descriptive analysis (percentage change) was used to test the hypothesis that in the intense physical work ergonomic stressors are variants in the different types of sickles used for harvesting operations of wheat crop. Whereas, a reviewed analysis is presented in the paper for metabolic acidosis in harvesting of the crop as an intense physical work.

III.RESULTS AND DISCUSSION

A. Anthropometric Measurements

Anthropometric measurement is the measurement of human body including body dimensions and the mechanical aspects of human motions including consideration of range of frequency in an ergonomic model. The Anthropometric measurements taken in this study were weight in kg, height in cm, Body Mass Index (BMI) in kg/m^2, eye height in cm, shoulder height, standing elbow height and standing knuckle height in cm. The readings of the selected sample for the women are depicted in Table I. The selected sample comprised of the women who carry out the harvesting operations in India in their seasonal activities.

TABLE I
ANTHROPOMETRIC MEASUREMENT OF THE SUBJECTS EMPLOYED FOR EXPERIMENTS

Anthropometric measurements (mean)						
Weight (kg)	Height (cm)	BMI (kg/m^2)	Eye height (cm)	Shoulder height (cm)	Standing elbow height (cm)	Standing knuckle height (cm)
47.39	152.2	20.34	140.2	126.2	98.91	68.91

Table II showed the physical fitness, which is the state of health of the selected women. It was assessed by using the following equation (Singh and Sharma, 2000):

$$\text{Physical Fitness Index (PFI)} = \frac{\text{Duration of exercise}}{\text{Sum of Ist, 2nd, 3rd recovery Pulse Count}} \times 100$$

Respondents ranked from poor to excellent on the basis of physical fitness index, which is Up to 80 (Poor physical fitness), 81-100 (Low average), 101-115 (High average), 116-135 (Good), 136-150 (Very good) and Beyond 150 (Excellent). The sample women were selected with high average to good physical fitness.

TABLE II
PHYSICAL FITNESS OF THE SELECTED SAMPLE WOMEN

Physical fitness index (PFI)	Step-stool test (%)
Poor	28.95
Low average	10.52
High average	31.58
Good	26.32
Very Good	2.63
Excellent	0.00

B. Grip Strength

All the respondents selected for the study were carrying out the harvesting of the crop by holding the plants with left hands and cutting the crop with sickles in their right hands. Table III reveals that the change in grip strength of left hand was 21.95 % for traditional sickle, 21.95 % with the Type A sickle and 22.32 % for the Type B sickle. Whereas, for the right hand it was decreased with 24.16 % for traditional sickle, 21.32 % with the Type A sickle and 19.32 % for the Type B sickle.

TABLE III
GRIP STRENGTH (Kg.) OF FARMERS USING HAND TOOLS FOR HARVESTING

Technology	**At Rest**		**After work**		**% change after work**	
	LH	RH	LH	RH	LH	RH
Type A	22.14	24.33	19.15	17.22	21.95	24.16
Type B	22.11	21.54	19.73	22.12	21.91	21.32
Type C	22.53	19.53	21.07	21.47	22.32	19.32

C. **Heart Rate**

The average resting heart rate of a healthy woman is 76 beats/min which increases successively when the individual gets on any physical work. The harvesting of the crop in summer season with the traditional sickle showed a change of 125.19 harvesting by traditional sickle, 123.19 by Type A sickle and 125.18 by Type B sickle. The percentage change in working heart rate was equally more than the Type C sickle (Table IV). "[11]" reported heart rate of 104.57 beats/min. by traditional sickle and 105.62 beats/min. by improved sickle. Whereas, average heart rate of 111 beats/min. by traditional sickle and 105.3 beats/min. by improved sickle was reported by [4].

TABLE IV

HEART RATE (beats/min.) OF FARMERS USING HAND TOOLS FOR HARVESTING

Technology	At Rest	After work	% change after work
Type A	81	126	125.19
Type B	81	124	123.19
Type C	82	126	125.18

D. Energy Expenditure

By taking average resting heart rate as reference the energy expenditure calculated for the harvesting activity of wheat in summer season by using the three different types of sickle depicted in table V that a 11.31 Kj/min. of energy in Type A sickle, 11.00 Kj/min. of energy in Type A sickle and 11.31 Kj/min. of energy in Type A sickle. The energy expenditure of 7.91 Kj/min. by traditional sickle and 8.07 Kj/min. by improved sickle was reported by [11]. Whereas, average heart rate of 9.00 Kj/min. by traditional sickle and 8.00 Kj/min. by improved sickle was reported by [4].

TABLE V

ENERGY EXPENDITURE (KJ/MIN.) OF FARMERS USING HAND TOOLS FOR HARVESTING

Technology	At Rest	After work	% change after work
Type A	4.16	11.31	11.27
Type B	4.16	11.00	10.96
Type C	4.32	11.31	11.27

E. **Total Cardiac cost of Work**

The sample women selected for the experiment were having 2.09 litre/min. aerobic capacity. After the harvesting wheat the TCCW was calculated. The table VI showed 2025 TCCW in Type A, 1935 in Type B and 1980 in Type C sickle. The TCCW of 402.35 litre/min. by traditional sickle and 256.93 litre/min. by improved sickle was reported by [11].

TABLE VI

TCCW (LITRE/MIN.) OF FARMERS USING HAND TOOLS FOR HARVESTING

Technology	After work
Type A	2025
Type B	1935
Type C	1980

F. **Fatigue and its metabolic acidosis**

The data in Table VII concluded that feeling of fatigue changed drastically to 59.48 % in Type A sickle, 29.96 % in Type B sickle and 48.40 % in Type C sickle. During severe physical work the increase in blood and muscle lactate and the coincident decrease in pH in both tissues have been traditionally explained by the production of lactic acid. Such a traditional interpretation assumes that due to the relatively low $_{p}$Ka (pH= 3.87) of the carboxylic acid functional group of lactic acid, there is an immediate and near total ionization of lactic acid across the range of cellular skeletal muscle pH (6.2-7.0)[12-20]. This interpretation is best represented by the content of numerous textbooks of physical work physiology, physiology and biochemistry that explain acidosis by the production of lactic acid, causing the release of a proton (H^+) and leaving the final product to the acid salt lactate. This process has been termed lactic acidosis [21]. According to this, if and when there is a rapid increase in the production of lactic acid, the free H^+ can be buffered by bicarbonate causing the non-metabolic production of carbon dioxide (CO_2). In turn, the developing acidosis and the raised blood CO_2 content stimulate an increased rate of ventilation causing the temporal relationship between the lactate and ventilator thresholds [22]-[25].

TABLE VII
LEVEL OF FATIGUE WHILE HARVESTING USING HAND TOOLS

Parameters	***At Rest***	***After work***	***% change after work***
Type A	59.63	14.62	59.48
Type B	30.25	29.50	29.96
Type C	48.61	21.03	48.40

An assessment of the biochemical reactions that support muscle energy catabolism reveals that proton balance in a muscle cell can be influenced by each of the phosphagen, glycolytic and mitochondrial respiration energy systems that function to produce cellular ATP. A review of each of these energy systems follows for the purpose of identifying the reactions involving proton release and consumption. The cellular store of creatine phosphate provides a near immediate metabolic system to produce ATP during the onset and initial seconds of muscle contraction. Creatine phosphate is also believed to be important for the general transfer of phosphate groups from the mitochondria throughout the cytosol, and as such could also be important for all metabolic states of skeletal muscle cells. The chemical structures of the substrates and products of the creatine kinase reaction are provided in Fig. 4. The creatine kinase reaction is alkalinizing to the cell, as a proton is consumed in this reaction. The proton is required to replace the phosphate group of creatine phosphate, completing the second amine (NH2) functional group of creatine. The increasing concentration of Pi during intense physical work is not the result of the creatine kinase reaction, as is often mistakenly interpreted. The accumulation of intramuscular Pi results from cellular conditions characterized by a rate of ATP demand that exceeds ATP supply from mitochondrial respiration. During these conditions there is an increased reliance on cytosolic ATP turnover (non-mitochondrial). Such added ATP hydrolysis produces Pi at a rate that now exceeds the rate of Pi entry into the mitochondria, causing Pi accumulation. More detailed content will be given to the cellular conditions associated with increasing non-mitochondrial ATP turnover, as this cellular condition causes acidosis. Glycolysis is fueled by the production of glucose- 6-phosphate (G6P), which is derived from either blood glucose or muscle glycogen. Despite glycogen providing the majority of carbohydrate that fuels muscle glycolysis during intense physical work, traditional biochemical explanations of glycolysis depict the pathway commencing with glucose and consisting of 10 reactions that result in pyruvate formation. The use of glycogen as the primary substrate (glycogenolysis) differs from glycolysis in bypassing the first reaction and thus shares the remaining nine reactions. This simple distinction between the glucose and glycogen origin of glycolysis is important, the proton release from glycolysis differs depending on whether glucose or muscle glycogen is used to form G6P and fuel glycolysis [7].

IV. CONCLUSION

It is inferred that the respondents find the type B sickle was worker friendly, ergonomically suitable and compatible which results in least perceived fatigue and recommended based on ergonomic stressors supported by its biochemical analysis for metabolic acidosis. Further studies can be carried out with the human samples for lactic acidosis and other ergonomic parameters in details.

REFERENCES:

1. R. Yadav, S. Pund, N. C. Patel, and L. P. Gite, "Analytical study of strength parameters of Indian farm workers and its implication in equipment design", *Agric Eng Int: CIGR Journal,* Vol. 12 No. 2, pp. 49-54, 2010.
2. S. J. Twomlow, D. H. O'Neill, B. Sims, J. Ellis-Jones, and T. Jafry, "RD—Rural Development: An Engineering Perspective on Sustainable Smallholder Farming in Developing Countries", *Annals of Arid Zone*, Vol. 38, pp. 93–135, 2002.
3. S. Singh, and O. Hensel, "Impact of extension education on improving knowledge of sustainable technical agricultural practices", *Agric Eng Int: CIGR Journal, Vol.* 16 No. 1, pp. 198-206, 2014.
4. P. Gupta, S. Singh, A. Singhal, S. jain, P. Mathur, and A. Choudhary, "Drudgery reduction of farm women through technology intervention in rural areas of Rajasthan", in Proc. Intl. conf. on emerg. Tech. in ag. And food eng., IIT kharagpur, 2004, pp. 331-337.
5. A. G. Rijk, "Agricultural mechanisation strategy", in *CIGR Handbook of Agricultural Engineering,* vol. III , B. A. Stout, and B. Cheze, Ed. ASAE: St Joseph 1999, pp. 536–553.
6. G. Brooks, "The lactate shuttle during physical work and recovery", Medicine & Science in Sports & Physical work, vol. 18 no. 3, pp. 360-368, 1986.
7. R. A. Robergs, "Biochemistry of physical work-induced metabolic acidosis", *AJP: Regulatory, Integrative and Comparative Physiology*, vol. 287, no. 3, pp. R502-R516, 2004.
8. E. I. U. Nwuba, and R. N. Kaul, "Energy requirements of hand tools for wood cutting", vol. 36, pp. 207-215, 1986.
9. J. A. Leblanc, "Use of heart rate as an index of work output", *Journal of Applied Physiology*, vol. 10, pp. 275-280, 1957.
10. C.W. Suggs, and . E. Splinter, "Time and energy analysis of agricultural tasks", *Transactions of the American Society of Agricultural Engineers*, vol. 1(1), pp. 50-52, 1958.
11. C. Badiger, S. Hasalkar, S. Huilgol, m, Hosakeri, and P. kavita, "Ergonomic assessment of improved agricultural technologies introduced for farm women in northern Karnataka", in Proc. Intl. conf. on emerg. Tech. in ag. And food eng., IIT kharagpur, 2004, pp. 321-325.
12. H. Hagber, "Intracellular pH during ischemia in skeletal muscle: relationship to membrane potential, extracellular pH, tissue lactic acid and ATP", *Pflu¨gers Arch*, vol. 404, pp. 342–347, 1985.
13. L. Lehninger, The Principles of Biochemistry (2nd ed). New York, Worth, 1982.
14. K. Sahlin, L. Edstrom, H. Sjoholm, and E. Hultman, "Effects of lactic acid accumulation and ATP decrease on muscle tension and relaxation", *Am J Physiol Cell Physiol*, vol. 240, pp. C121–C126, 1981.
15. K. Sahlin, R. C. Harris, B. Nylind, and E. Hultman, "Lactate content and pH in muscle samples obtained after dynamic physical work", *Pflu¨gers Arch* vol. 367, pp. 143–149, 1976.
16. K. Sahlin, and J. Henriksson, "Muscle buffer capacity and lactate accumulation in skeletal muscle of trained and untrained men", *Acta Physiol Scand,* vol. 122, pp. 331–339, 1984.
17. K. Sahlin, A. Katz, and J. Henriksson, "Redox state and lactate accumulation in human skeletal muscle during dynamic physical work" *Biochem J,* vol. 245, pp. 551–556, 1987.
18. K. Sahlin, M. Tonkonogi, and K. Soderlund, "Energy supply and muscle fatigue in humans", *Acta Physiol Scand,* vol. 162, pp. 261–266, 1998.
19. K. Sahlin, "Metabolic changes limiting muscle performance", in *Biochemistry of Physical work*, vol. 16, B. Saltin, I. L. Champaign, Human Kinetics, 1986, pp. 323–344.
20. L. Stryer, Biochemistry (4th ed), San Francisco: Freeman, 1995.
21. M. E. Laski, and D. E. Wesson, "Lactic acidosis" in *Acid-Base and Electrolyte Disorders: A Companion to Brenner and Rector's The Kidney*, T. D. DuBose, and L. L. Hamm, Philadelphia, PA: Saunders, 2002, pp. 835–108.
22. A. Katz, and K. Sahlin, "Regulation of lactic acid production during physical work", *J Appl Physiol*, vol. 65, pp. 509–518, 1988.
23. R. Margaria, H.T. Edwards, and D. B. Dill, "The possible mechanisms of contracting and paying the oxygen debt and the role of lactic acid in muscular contraction", *Am J Physiol,* vol. 106, pp. 689–715, 1933.
24. K. Sahlin, A. Katz, and J. Henriksson, "Redox state and lactate accumulation in human skeletal muscle during dynamic physical work" *Biochem J,* vol. 245, pp. 551–556, 1987.
25. W. Stringer, R. Casaburi, and K. Wasserman, "Acid-base regulation during physical work and recovery in humans", *J Appl Physiol,* vol. 72, pp. 954–961, 1992.