Role of Energy Expenditure in the Evaluation of Lathe Operator Performance

Shahnawaz Mohsin[1], Imtiaz Ali Khan[2] and Mohammad. Ali[3]

[1]MES, Aligarh Muslim University, Aligarh, UP, India
[2&3]MED,Aligarh Muslim University, Aligarh, UP, India

Abstract: For evaluating a work station, energy expenditure plays a vital role as far as the worker's safety, health and efficiency of performing tasks in the most effective and efficient manner are concerned. This study has been carried out for finding the amount of energy spent by the application of Energy Expenditure Prediction Program. The energy expenditure was determined by observing and recording the activities during the machining operations of a lathe machine.

In this work the mean metabolic energy rate is estimated by knowing the energy expenditure and task duration. The method used in this work is more accurate and viable and less exorbitant than laboratory methods such as measurement of oxygen intake. The technique used in this work provides an objective rate to measure worker fatigue.

The study identifies the degree of physical work based on the energy spent in various activities in the experiment and activities that have a higher energy expenditure can be ergonomically designed.

KEYWORDS: Ergonomic, Evaluation, Energy expenditure, Lathe Machine.

DOI of the Article: https://doi.org/10.46501/IJMTST0708033

Available online at: http://www.ijmtst.com/vol7issue08.html

As per UGC guidelines an electronic bar code is provided to seure your paper

To Cite this Article: Shahnawaz Mohsin, Imtiaz Ali Khan and Mohammad. Ali. Role of Energy Expenditure in the Evaluation of Lathe Operator Performance. *International Journal for Modern Trends in Science and Technology* 2021, *7*, 0708068, pp. 203-212. https://doi.org/10.46501/IJMTST0708033

Article Info. Received: 09 August 2021; Accepted: 21 August 2021; Published: 25 August 2021

INTRODUCTION

A. *Ergonomics*

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. Ergonomics is concerned with the "fit" between the user, equipment and their environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, functions, information and the environment suit each user. To assess the fit between a person and the used technology Ergonomics draws on many disciplines in their study on human and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, kinesiology, physiology, cognitive physiology. Ergonomics in its application has an interdisciplinary approach, with the ultimate objective of improving the level of comfort.

The branch of ergonomics can be divided into three broad categories: -

B. *Physical ergonomics*

Physical ergonomics is concerned with human anatomy, and some of the anthropometric, physiological and bio mechanical characteristics as they relate to physical activity. Physical ergonomic principles have been widely used in the design of both consumer and industrial products.

C. *Cognitive ergonomics*

Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.

D. *Organizational ergonomics*

Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes. Relevant topics include communication, crew resource management, work design, work systems, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work programs, virtual organizations, telework, and quality management.

Skeletal muscles may be thought of as biochemical machines with chemical energy stored in adenosine triphosphate (ATP) going into the muscles and being converted to mechanical work and heat energy [1]and [2]. In other words, the total metabolic energy expenditure will be transformed mainly into the sum of the work done by the joint actuator torques, heat energy dissipation and basal metabolic energy. In the case of static loading – where the mechanical work done by muscle is zero – the muscle energy is all dissipated as heat. Mechanical power is expressed as the product of joint actuator torque and joint velocity. The total mechanical power of the system is determined as the sum of mechanical power of all the joints.

Ergonomist, applied physiologist, sports scientist, nutritionist and epidemiologist require the estimates of activity patterns and energy expenditures. Methods generally used for measurement of energy expenditure are: -

- 'Gold Standard' Method
- Cosmed K4b2 (Rome, Italy) Portable Indirect Calorimeter
- Metamax (Borsdorf, Germany)
- Medgraphics VO2000
- Accelerometer
- Portable Metabolic Unit
- Pedometer
- Polar Heart Rate Monitor
- Doubly Labelled Water
- Multiple Inertial Sensors
- Motion Sensors
- Combined Heart Rate and Motion Sensor
- Combined Heart Rate and Questionnaire Methods
- Integrated Electromyography
- Pulmonary Ventilation Volume
- Thermal Imaging
- Flex-Heart Rate Method

Recent technological advancements in the sensor technology along with the great progress made in algorithms have made accelerometers a powerful technique often used to assess everyday physical activity. Energy expenditure consists of following three components: -

- Maintenance expenditure
- Diet-induced energy expenditure
- Activity-induced energy expenditure

E. Literature Review

A muscle energy expenditure model was used to predict the release of thermal and mechanical energy during simulated muscle contractions [2].The muscle energy model is evaluated at different levels of complexity, from simulated contractions of isolated muscle to locomotion simulations of the entire body. In all cases, an acceptable agreement was found between simulated and experimental energy release.[3]investigate four household tasks at their own pace (sweeping, cleaning windows, vacuuming and mowing the lawn), performing in the subjects' homes and in a standardized laboratory environment. Energy expenditure was predicted by indirect methods. The specific results that specific household chores can contribute to 30 minutes. per day of moderate intensity activity required to confer health benefits. However, the significant variability between subjects in energy expenditure resulted in some people performing these tasks with a light intensity. The relative differences in metabolic equivalents (MET) between home and laboratory emphasize the effects of 'environment and terrain' and the 'mental approach to a task' on energy expenditure at its own pace.

[4]reviewed and evaluated the metabolic needs, fuel utilization and the relative thermal effect of different food, beverage, drug and emotional components to measure energy expenditure in humans. He recommended that when high precision is required and that he has had the resources available, he can use an indirect open-circuit calorimeter, while when the resources are limited and / or he can sacrifice the optimum accuracy, flexible total collection systems and methods Non-calorimetric ones are potentially useful if the limitations of these methods are appreciated. To obtain specific information about free subjects, the factorial method is used.

[5]Expected energy expenditure of physical activity (PA), heart rate (HR) and anthropometry in women tea pickers in India. An energy expenditure prediction (EE) equation was generated using a branched method that first distinguishes time during normal work day activities (rest, arrangement and walking) using accelerometer counts. EE at rest is estimated from age and weight, while EE not at rest minute by minute is estimated from HR and body mass index BMI. It concludes that energy expenditure can be accurately predicted with a branched equation based on PA, HR, age, weight and height for a specific population that participates in a known set of activities. Very little is known about the longitudinal changes in energy requirements at the end of life.

[6]The determinants of this study were: (i) determine energy requirements in adulthood and how it changes over a period of 7 years, (ii) determine if changes in fat-free mass (FFM) were related to changes in resting metabolic rate (RMR), and (iii) determine the accuracy of total expected energy expenditure (TEE) to measure TEE. He concluded that the TEE, the RMR and the energy expenditure of the activity (AEE) decreased in men, but not in women, from the 8thto the 9thdecades of life. The dietary reference intake (DRI) equation for predicting TEE was comparable to the measure of TEE, while the World Health Organization (WHO) equation predicted TEE in the elderly population.

Non-calorimetric methods [7] for estimating energy expenditure are often used due to their ease of use and relative economy. These methods estimate energy expenditure through physiological variables that are related to energy expenditure such as muscle and heart rate activity. These methods have been standardized and validated using calorimetric methods. [4].

Five different methods were also used like integrated electromyography, pulmonary ventilation volume, flex-heart rate method,thermal imaging, and the doubly labelled water method. The model for predicting human total energy expenditure (TEE) [7],

the Factorial Method, considerably underestimates actual TEE, mainly among highly active populations. In this study, the Allocation Model is presented for speculating TEE. Unlike the Factorial Method, the Allocation Model includes metabolic cost terms for both thermoregulation and the thermic effect of food, as well as using more precise basal metabolic rate and activity cost assessments. The Allocation Model was tested using doubly labeled water and flex-heart rate measured TEEs of healthy and highly active adults. The results propose the Allocation Model is a powerful new toolthat should be used in place of the Factorial Method for assessing human TEE, and can be used to evaluate adaptations, life history strategies and differential energy allocation among highly active humans in natural environments.

F. Problem Statement

The worker on a lathe machine spends a lot of time during the machining operations. Work activities of physical effort such as material handling, supply and movement of tools and work. Therefore, professions such as production and frequency of workers have spent moderate to high levels of physical energy to perform jobs. Back injuries due to excessive strain are common in most professions. A high level of physical exertion can cause stress and tension. The factors that influence energy consumption are work methods, work posture, work frequency and instrument design.In this study, the energy expenditure was determined by observing and recording the activities during the machining operations on a lathe machine.

In this work the average metabolic energy rate is predicted knowing the energy expenditure and the duration of the activity. Metabolic energy is calculated by dividing work into tasks or activity elements.

Several cognitive tests were performed before beginning the experiment and, based on acceptable results, the subject was selected to determine and evaluate their energy expenditure on the lathe.

G. Design Tools for Cognitive Tests

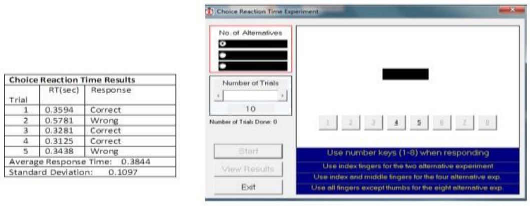
Cognitive tests are assessments of the cognitive capabilities of humans. Before conducting the experiment, it is required to have a preliminary investigation for work assignment like:

Simple Reaction Time Experiment, Choice Reaction Time Experiment, Psychophysics – Line Length Judgment, Fitts Tapping Task, Short Term Memory Span, Stroop Test, Visual Inspection- Resister inspection.

The subject for the experiment was selected on the basis of these various cognitive tests Fig. 1. For above cognitive tests, Design Tools Laboratory Software[9] was used.

On the basis of these tests the experiment was started and then energy expenditure of lathe work environment was evaluated.

(a) Simple Reaction Time Experiment



(b) Choice Reaction Time Experiment

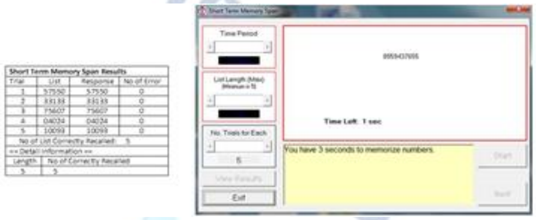


Figure1

METHODS

A. Experimental Setup

Literature revealed that for carrying out experimental investigations, it is best to perform in the work field of industrial environment to incorporate utmost realistic conditions and achieve precise results. The experiment was conducted at University Polytechnic Workshop, AMU Aligarh.

The experimental set up comprised of the following components: -

1) A conventional Lathe Machine.
2) A light cylindrical job.
3) Single point cutting tool.
4) Vernier Calipers.
5) Video Camera for recording.

The conventional lathe machine environment includes the lathe machine, a light cylindrical job of about **0. 34kg.**The material selected is of mild steel having density as **7.85 g/cubic cm**.The initial dimension of the work piece is of diameter **25 mm** and length as **105 mm** and the initial volume of job is **47.5 cubic cm** and a rack of suitable dimension used for keeping tools was used as shown in Fig. 2.

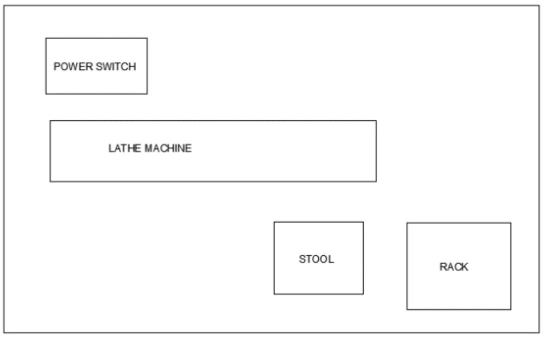


Figure 2Schematic diagram of the Experimental setup

The Schematic diagram of the experiment set-up employed in the experimental investigation undertaken in the present work is shown inFig.2.

The working environment conditions like temperature, sound level and illumination level was tested. The average wet bulb temperature was **31˚C** and average dry bulb temperature was **34˚C**. Illumination level maintained was **46LUX** on m/c and **34 LUX** on working area. Sound level throughout the experiment is recorded and is found within the acceptable range **as 110dB (Max), 97dB (Normal) and 108(Peak)** and verified by the Design Tools Laboratory Program [9].

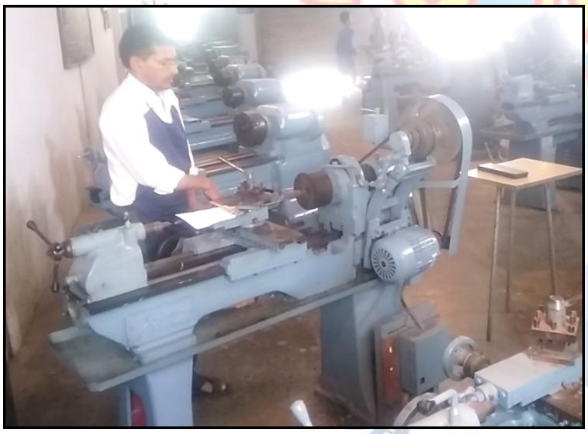


Figure 3Experimental setup

As shown in Fig.3the operator is standing in front of the lathe machine at a comfortable distance for performing the experiment.

B. Subject

The subject for the experiment was selected on the basis of various cognitive tests. For this cognitive test, [9] was used. The findings of these tests have resulted average simple reaction time **0.3898 sec**. and its standard deviation as **0.0293**.

Through the same test, it was recorded that the average choice reaction time and corresponding standard deviation **0.01097**. In short memory span test, the subject was asked to enter five digit numbers after **20** seconds the result obtained was the length as 5 and number of correctly recalled as 5, implies that the response was **100%**. This result indicates that the subject selected for the concerned experiment is successful in short term memory test and fit for the concerned task.

The age of the subject was **49 yrs. old** and height was **153 cm** having experience of **25 years** working on lathe machine.

On the basis of these tests the experiment was started and then energy expenditure of lathe work environment was evaluated.

C. Experimental Procedure

After conducting the cognitive tests on the subject and Before starting the experiment, the subject was given sufficient instructions to perform the job. A heavy work piece of dimension **Ø24mm x 105 mm** length of mild steel was selected. The operations performed on the work piece for energy expenditure measurements were **Loading, Facing,Turning, Finishing and Unloading**. The activities like **machine ready** and **switch on, setting and adjusting, loading, unloading,execution** and **switching off** the machine was recorded through Lenovo mobile video camera.

The recording was done on working hours for about **0.5 hr.** After recording each and every task, a software name as Energy Expenditure Prediction Program (EEPP) [10] was used to analyze the energy rate. For this, the job work was divided into 12 tasks and each task was further divided into various elements. **Task1** consists of **1** element, **Task2** consists of **3** elements, **Task3** consists of **2** elements, **Task4** consists of **8** elements, **Task5** consists of **5** elements, **Task6** consists of **3** elements, **Task7** consists of **3** elements, **Task8** consists of **3** elements **Task9** consists of **4** elements,**Task10** consist of **1** element,**Task11** consist of **1**element and **Task12** consist of **1**element. The energy expenditure for various tasks was determined using EEPP. The work piece which was used for the experiment has been shown in Fig.4 and Fig.5which shows the initial and final dimension of job in 3D Model & actual view respectively.

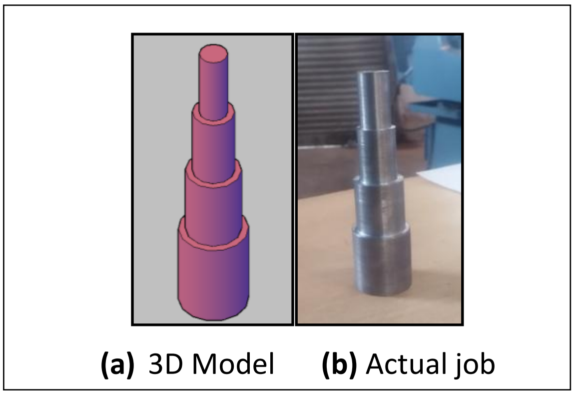


Figure 4 Mild Steel Job(Final)

Final 2-D model dimension in mm of the work piece geometry (2D) used for measurement of energy expenditures is shown in Fig.5.

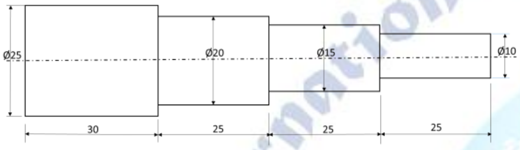


Figure 5Work piece (2D) manufactured for energy expenditure measurements

The recorded time of every element is entered in the EEPP. The weight of operator, weight of job and postures of the operator for every task element like stoop, squat, sitting standing, push, pull, hand work, arm work etc. are entered. After entering every detail of all Task Elements, EEPP calculates the Total Posture Energy, Total Elements Energy, Cycle Energy, Total Task Energy and Task Energy Rate. The Energy Expenditure detailed report is generated by the program for every task which is then used for analyzing the result.

The following screenshot in Fig.6 example illustrates EEPP after the data has been entered.

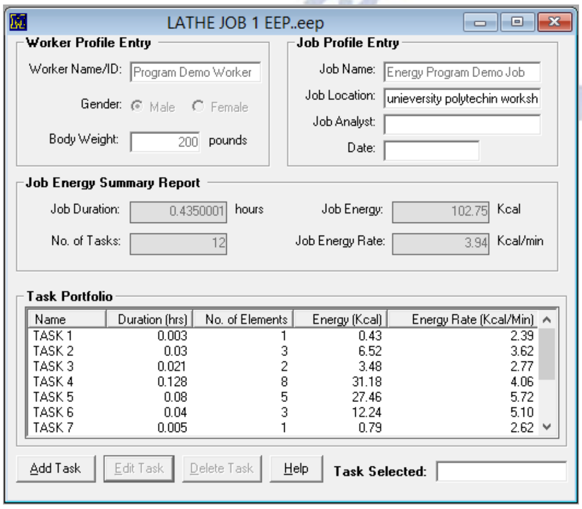


Figure 6 Screenshot of EEPP showing task information

The energy expenditure for the various task and their respective elements was determined using EEPP after inputting the recorded data.The EEPP analyze and determine the average metabolic energy rate of the task by knowing the energy expenditure of the time duration of the task. The following Table 1 shows the task description.

Table ITask Elements for determining the energy expenditure

TASK NO	TASK NAME	NO. OF ELEMENTS	NAME OF ELEMENTS
1	Putting all the tools on rack.	1	Carry
2	Loading the tool and work piece on the machine	3	Hand Work Arm work Carry
3	Facing of the work piece	2	Arm work
4	Rough turning of the work piece	8	Arm work
5	First Step turning of work piece	5	Arm work
6	Second Step turning of work piece	3	Arm work
7	Setting of the job on the chuck again	1	Hand Work
8	Facing operation on other side of work piece	3	Arm work
9	Third Step turning of work piece	4	Arm work
10	Unloading the job and switching off the machining.	1	Hand Work
11	Putting the entire tool on the rack	1	Carry
12	Cleaning of the machine	1	Hand Work

Some of the pictures taken while performing the experiment of all the task operation regarding the present study have been shown below in Fig.7.

(a) Loading

(b) Facing

(c) Rough facing

(d) Turning

Figure 7 Subject performing the task

RESULTS AND ANALYSIS

A. *Result*

An overview of the literature on human performance studies using energy expenditure in the context of the lathe environment indicated that little or no area was considered in this previous research. On the other hand, the use of lathe machines worldwide is increasing day by day. Today, a large part of the workforce is associated with work on lathe machine tools. Human-machine interaction is already playing a vital role in the entire production process, from planning individual connections in the production chain to designing the finished product. The innovative technology is made for man, used and monitored by man. Therefore, the products must be reliable in operation, safe, profitable, accepted by the staff and, last but not least, the energy expenditure will be within the allowed limit. This interaction between technology and user, known as human-machine interaction, is therefore the heart of industrial production. Taking these considerations into account, this study was designed to explore how energy expenditure can be determined in a conventional lathe environment using the energy expenditure prediction program [10]. Further, the study also aimed at to compare the determined energy expenditure with standards set by various agencies.

The summary and detailed report of every task was generated using EEPP after inputting the recorded data.

The result obtained for skilled worker after providing all information to the program has been shown in the Table 2 which indicates the energy expenditure measurements for various tasks on lathe machine ready for operation, loading of the job, movement from rack to machine and loading work piece, tool and machine setting, task operation execution like loading, facing, turning,finishing and unloading work piece and movement from machine to rack and cleaning.

B. *Job Energy Expenditure Summary Report*

Worker Profile

Worker Name/ID: Mr. Jabruddin

Gender: Male

Body Weight: 150 pounds

Job Profile

Job Name: Energy Count on a Lathe Job.

Job Location: UniversityPolytechnic Workshop, AMU, Aligarh, UP, India.

Task Portfolio

Job Duration: 0.4350001 hours

No. of Tasks: 12

Job Energy: 102.75 Kcal

Job Energy Rate: 3.94 Kcal/min

Table II Task Energy Expenditure Summary

Name	Duration (hrs.)	Elements	Energy (Kcal)	Energy Rate (Kcal/ min)	Description
TASK 1	0.003	1	0.43	2.39	Putting all the tools on rack
TASK 2	0.03	3	6.52	3.62	Loading the work piece on machine
TASK 3	0.021	2	3.48	2.77	Facing of the work piece
TASK 4	0.128	8	22.80	3.37	Rough turning of the work piece
TASK 5	0.08	5	15.26	3.18	First Step turning of work piece
TASK 6	0.04	3	6.28	2.62	Second Step turning of work piece
TASK 7	0.005	1	0.79	2.62	Setting of the job on the chuck again
TASK 8	0.02	3	4.18	3.48	Facing operation on other side of work piece
TASK 9	0.05	4	7.86	2.62	Third Step turning of work piece
TASK 10	0.002	1	0.28	2.32	Unloading the job and switching off the machining
TASK 11	0.006	1	0.93	2.57	Putting the entire tool on the rack
TASK 12	0.05	1	7.4	2.47	Cleaning of the machine

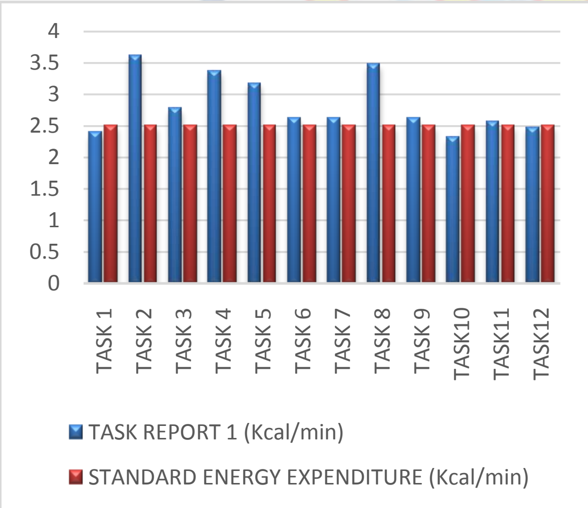


Figure 8Graph for comparison of measured data in report 1 and standard energy expenditure during tasks of the experiment

DISCUSSION AND CONCLUSION

The World Health Organization (WHO) and the Occupational Health and Safety Administration (OSHA) believe that work-related energy costs have multifactorial causes. Management and workers are very concerned about the work environment, ergonomics, work quality and safety and health at work. Advances in information and communication technologies and specialized work that requires repetitive tasks have led to the need to design the human-machine interface in terms of energy expenditure.

This study presented an effective approach to evaluating a lathe environment using the energy expenditure prediction program. For various activities, a detailed report through the software[10]was generated for the analysis and compared with standards [11]. On the basis of present study for skilledworkers as shown in Fig. 8, the following concluding remarks are drawn.

(i) The energy expenditure of **Task 1** i.e. during**putting all the tools on rack** determined through energy expenditure predictionprogram is**0.43 kcal** and the energy rate is **2.39 kcal/min**. This energy is well within standard level (2.5 kcal/min), therefore, it is concluded that the concerned task is ergonomically designed.

(ii) The energy expenditure of **Task 2** i.e. during **loading the work piece on the machine**determined through energy expenditure prediction programis **6.52 kcal** and energy rate is **3.62 kcal/min.** This energy is so **a bit higher** as compared to standards, and therefore it is concluded that further ergonomic designs of the lathe environment is required.

(iii) The energy expenditure of **Task 3** i.e. during **the facing of the work piece** is **3.48 kcal** and energy rate is **2.77 kcal/min.** This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(iv) The energy expenditure of **Task 4** i.e. during **rough turning of the work piece** determined through energy expenditure prediction program is **22.80 kcal** and energy rate is **3.37 kcal/min**. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(v) The energy expenditure of **Task 5**i.e.during**first step turning of work piece**determined through energy expenditure prediction program is **15.26 kcal** and energy rate is **3.18 kcal/min**. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(vi) The energy expenditure of **Task 6**i.e.**second step turning of work piece**is **6.28 kcal** and energy rate **is 2.62**

kcal/min. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(vii) The energy expenditure of **Task 7 i.e. setting of the job on the chuck againis 0.79 kcal** and energy rate is **2.62 kcal/min**. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(viii) The energy expenditure of **Task 8** i.e. during **facing operation on other side of work piece** is **4.18 kcal** and energy rate is **3.48 kcal/min**. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(ix) The energy expenditure of **Task 9** i.e. during **third step turning of work piece** is **7.86 kcal** and energy rate is **2.62 kcal/min**. This energy is higher as compared to standards; therefore, it is concluded that further ergonomic designs of the lathe environment is required.

(x) The energy expenditure of **Task 10** i.e. during**Unloading the job and switching off the machining** determined through energy expenditure program is **0.28 kcal** and energy rate **is 2.32 kcal/min**. This energy is less as compared to standards; therefore, it is concluded that the task need not to be ergonomically designed.

(xi) The energy expenditure of **Task 11 i.e.** during **putting the entire tool on the rack** is **0.93 kcal** and energy rate is **2.57 kcal/min**. This energy is not so much high as compared to standards, therefore it is concluded that the concerned task is in within limits and less attention is needed.

(xii) The energy expenditure of **Task 12 i.e.** during**cleaning of the machine** determined through energy expenditure predictionprogram is**7.40 kcal** and the energy rate is **2.47 kcal/min**. This energy is low as compared to standards, therefore it is concluded that further ergonomic designs of the lathe environment is not required.

Table IIIPriority for every task after comparison

Task	**Task name**	**expenditure (Report 1)**	**expenditure (Report 2)**	**Standard Energy Expenditure (kcal/min)**	**Remark**	**Priority**
1	Putting all the tools on rack	2.39	2.43	2.5	Well Ergonomically designed	12
2	Loading the tool and work piece on the machine	3.62	2.37	2.5	Ergonomic design is required	1
3	Facing of the work piece	2.77	2.81	2.5	Less attention is required	6
4	Rough turning of the work piece	3.37	3.4	2.5	Ergonomic design is required	3
5	First Step turning of work piece	3.18	3.41	2.5	Ergonomic design is required	5
6	Second Step turning of work piece	2.62	2.4	2.5	Less attention is required	7
7	Setting of the job on the chuck again	2.62	2.68	2.5	Less attention is required	8
8	Facing operation on other side of work piece	3.48	2.66	2.5	Ergonomic design is required	2
9	Third Step turning of work piece	2.62	3.26	2.5	Less attention is required	9
10	Unloading the job and switching off the machining.	3.32	2.2	2.5	Ergonomic design is required	4
11	Putting the entire tool on the rack	2.57	2.32	2.5	Less attention is required	10
12	Cleaning of the machine	2.47	2.18	2.5	Well Ergonomically designed	11

Future Scope for the study

The study was conducted in a limited time frame, better result can be obtained if conducted over a long range of time with many workers and for many work pieces to see the effect with large number of trials also it would reduce error of acquaintance. Furthermore, the study can be done on mass production environment so as to evaluate and determine the energy expenditure of many workers. In this way better results will be obtained and further ergonomic design can be possible.

The study can help to keep the energy expenditure within bounds and recommended limits. It can help to improvise the method of work, work posture, methodology, work rate and also tool design so as to reduce the fatigue, failure, injuries, WMSD's, overexertion etc.

In this way the health of worker, his strength, endurance could be maintained and finally the better ergonomic workstation can be suggested.

This method can be used to find the energy expenditure of any task because it is cheap and more accurate and feasible than any other techniques so it can be used for any work environment.

ACKNOWLEDGEMENT

The author would like to thank, Principal, University Polytechnic, AMU Aligarh., for providing the resource and Mr. Jabruddin, Technical Assistant for helping in conducting the experiment.

REFERENCES

[1] L. Sherwood, *Human physiology: from cells to systems (Brahm U,Pendit, Penerjemah)*. 2012.

[2] B. R. Umberger, K. G. M. Gerritsen, and P. E. Martin, "A Model of Human Muscle Energy Expenditure," *Comput. Methods Biomech. Biomed. Engin.*, vol. 6, no. 2, pp. 99–111, 2003.

[3] S. M. Gunn *et al.*, "Measurement and prediction of energy expenditure in males during household and garden tasks," *Eur. J. Appl. Physiol.*, vol. 91, no. 1, pp. 61–70, Jan. 2004.

[4] J. A. Levine, "Measurement of energy expenditure.," *Public Nealth Nutr.*, vol. 8, no. 7A, pp. 1123–1132, Oct. 2005.

[5] Eric M. Przybyszewski, "Predicting energy expenditure from physical activity, heart rate and anthropometry in female Indian tea pluckers," no. May, pp. 1–33, 2011.

[6] N. Sacktor *et al.*, "Longitudinal psychomotor speed performance in human immunodeficiency virus-seropositive individuals: Impact of age and serostatus," *J. Neurovirol.*, vol. 16, no. 5, pp. 335–341, 2010.

[7] C. Ocobock, "Measuring and Predicting Total Energy Expenditure Among Highly Active Humans in Natural Environments," 2014.

[8] Benjamin W. Niebel and Andris Freivalds, "Design Tools Laboratory Software for Methods, Standards, and work Design (11thed.)." 2001.

[9] Energy Expenditure Prediction Program 2.0.6, 2004, University ofMichigan Software, Michigan 48109-128.http://c4e.engin.umich.edu/tools-services/eepp-home/eepp-download/

[10] Mark S. Sanders, Ernest J. McCormick, 1992, Human FactorsIn Engineering and Design, McGraw-Hill, New York

