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DETERMINING ERGONOMIC FACTORS OF LOADING MACHINES USING IN FORESTRY OPERATIONS IN TURKEY

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ABSTRACT

Loading machines in various types are generally used in forest depots in Turkey for loading and stacking the forest products. However, the risks accompanying this development threaten the health of the operators working in loading machines. The aim of this study is to examine the working conditions of the operators of loading machines being used in forest operations in Turkey in terms of ergonomics. This study was applied on machines and operators 45 each, working in loading and stacking operations in forest depots within the borders of Western Black Sea Region. Physiological workload and ergonomic factors influencing the workload were evaluated with principal component analysis. The average physiological workload was calculated as 49% and it was in the category of "medium heavy work". It was also determined that the most important factors influencing the physiological workload during the operations were; body weight, machine technology and noise, anthropometric lengths, vibration, work technique, the length of the operator's arm, climate factors, social position, the surface of the terrain, the duration of the use of machine and the seat, motivation, smoking and proceeding speed of the machine.

Keywords: Ergonomics, Forestry, Loading machine, Physiological workload.

INTRODUCTION

Loading operations are quite important in terms of time and cost and regular flow of transportation operations in the production phases of raw materials obtained from wood. Using machines in loading operations has been increasing continuously in Turkey for the past 10-15 years due to high productivity in machine operations and difficulty in finding workers. However, ergonomic principles such as noise, vibration, anthropometric dimensions and physiological workload aren't assigned required importance in loading operations with tractors.

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In recent years, mechanization and automation in workplaces have developed and as a result, workload has increased considerably (Hirai 2006). In order to ease working conditions and facilitate the use of machines, operators are considered with the machine they operate. Work physiology studies the relation between human body and work. The aims of work physiology are; to study the relation between worker and working conditions, set rules regarding these relations, ensure that labor force is protected, increase productivity and to research the appropriate working style for the work in question (Yıldırım 1989).

Heart rate is used to determine and describe the state of health (Astrand et al. 2003). Moreover, physiological measurements including heart rate are reliable means to ascertain workload (Roja 2005). The relation between heart rate and physiological parameters has been studied in lots of scientific research (Lass et al. 1997). There are a limited number of ergonomic researches on loading-unloading machines in Turkey (Acar and Topalak 2001; Tunay et al. 2006). Most researches are usually concerned with the comparison of loading by hand and loading by machines in terms of cost and productivity. No serious research has been carried out on operators' health, safety and education although loading with machines is frequently applied currently. Furthermore, even though general ergonomic studies have been carried out on forestry machines in world countries (Gellerstedt 1999, Shemwetta et al. 2002, Neitzel and Yost 2002), no ergonomic study has been found specifically on loading machines.

The aim of this study is to examine the working conditions of the operators of loading machines used in forestry operations in Turkey in terms of ergonomics. In the study, ergonomic factors affecting the physiological workload of operators during the operations with loading machines were evaluated. During the operations with loading machines, factor analysis was applied using on site measurements regarding the ergonomic factors such as physiological workload, anthropometric dimensions, noise and vibration. As a result, ergonomic precautions that must be taken to protect the operators while working with loading machines used in forestry operations in Turkey were presented.

MATERIALS AND METHODS

This study was carried out in forest depots in Western Black Sea Region, which is rich in forest resources in Turkey. Ergonomic measurements on site were made during the operations with loading machines in September, October, November 2007 and in March, April, May 2008. The measurements used in the study were made during the operations of International, Ford and Massey Ferguson tractors on which loading equipment is mounted and original loading machines such as Komatsu and Hidromek.

Heartbeats of operators at work and at rest were measured so as to determine the physiological workload. Physiological workload was determined using heartbeat per minute (pulse) telemeter method. Polar S610i pulse meter and polar belt were used to have information about pulse and workload. Operators' pulse values in every 5 seconds at rest and at work were saved in the memory of the pulse meter. And then, the pulse values were transferred into computer using a software program. With the help of the pulse values while working with machines and at rest, the rate of physiological workload can be calculated (Shemwetta et al. 2002, Vitalis 1987, Kirk and Sullman 2001). As a result of the calculations, it was determined the loading operations under which work group are evaluated in terms of physiological workload.

Statistical analyses were made so as to determine the factors which affect the physiological workload of operators while working with machines used in forestry. Firstly, all the factors that may have an effect on workload were put forth after being discussed among experts. In log loading and stacking operations, in order to find out the factors that affect workload; operators, loading machines, working areas, anthropometric dimensions and noise and vibration etc. characteristics in different regions were determined.

Operator characteristics; age of the operator, total years worked, daily working time, occupational educational status (1: no training, 2: trained slightly, 3: trained), monthly wage of operator, working time within a day, smoking status (0: not smoking, 1: occasionally, 2: pack a day, 3: more than one pack), alcohol consumption (0: not drinking, 1: rarely, 2: one a week, 3: a little daily, 4: excessively a day), sports activity of operator (1: slightly, 2: moderately, 3: permanently), working situation of operator (1: civil servant, 2: worker of private enterprise, 3: own work), social requirement situation (according to Maslow; 1: no fulfillment, 2: intermediate, 3: satisfactory), improvement need situation (according to Maslow; 1: no fulfillment, 2: intermediate, 3: satisfactory), situation of realization oneself (according to Maslow; 1: no fulfillment, 2: intermediate, 3: satisfactory).

Machine characteristics; machine type (1: mounted agricultural tractor, 2: original), Loader type (1: back shovel, 2: front loader), age of the machine, Cabin status (1: no cabin, 2: only roofed, 3: original completely closed cab), situation of air conditioner (1: without air conditioner, 2: only fan, 3: air conditioned), front wheel pressure, rear wheel pressure, proceeding speed of the machine, seat use duration, seat suspension system (1: useless, 2: middling quality, 3: effective).

Working area characteristics; Altitude, pressure, temperature, relative humidity, wind velocity, slope, clothing insulation value (clo; 0.4: summery clothes, 0.6: light working clothes, 1.0: normal working clothes, 1.2: light outdoor clothes, 1.4: normal clothes, 1.7: wintery clothes), ground type (1: soil, 2: stabilized), ground hindrance (1: low hindrance, 2: middle hindered, 3: high hindrance), ground soil status (1: wet peat lands, 2: soft soil on a wet land, 3: soft soil on a dry land, 4: hard mineral soil, 5: sandy-graveled soil).

Anthropometric characteristics; stature, sitting height, knee height, shoulder breadth, hip breadth, chest depth, abdominal depth, shoulder-elbow length, elbow-fingertip length, upper limb length, hand length, vertical grip reach-standing, vertical grip reach-sitting, triceps skinfold, supraspinale skinfold, subscapular skinfold, upper arm girth, calf girth, body weight, operator's arm force.

Noise and vibration characteristics; x-axes weighted acceleration (Rms-x), y-axes weighted acceleration (Rms-y), z-axes weighted acceleration (Rms-z), total vibration magnitude (Rms- sum), Total vibration dose value (VDV), noise, maximum noise.

Correlation analysis was made to ascertain the relations among all the variables that may affect physiological workload. Then, factor analysis (Principal Component Analysis) that categorizes a number of variables which affect physiological workload under certain factor groups was made. In loading operations, it is quite difficult to determine the workload in accordance with each of the 59 variables. Therefore, in forestry, workload is brought about by a number of factors among which there are complicated interactions. Moreover, more than one variable may be found affecting the workload at the same rate. Hence, it is intended to measure the workload taking the most significant variable into consideration instead of focusing on too many variables. Determination of the most significant variables and interpretation of factors were realized according to varimax transformed factor matrix which was obtained as a result of rotation and had higher practical value.

RESULTS

In this part, first of all, a general outline of the physiological workload such as pulse values and maximum heart rate belonging to operators of loading machines was formed. And then, statistical analyses were made so as to determine the most effective factors on physiological workload. Average and standard deviation values belonging to some variables obtained as a result of measurements and examinations carried out during the operations with loading machines are determined. Correlation analysis was applied among 59 variables which were considered to have an effect on the operator in terms of ergonomics in the operations with loading machines. When the mutual interactions were studied, the highest positive correlations were found between the machine type and air conditioning(r=0.937), skinfold between the stomach and rib and below the omoplate (r=0.859), stature and sitting height (r=0.835), weight and omoplate skinfold (r=0.714) and operator age and experience (r=0.681). On the other hand, the highest negative correlations were found between state of the cabin and noise transmitted to operator (r=-0.796), temperature and humidity (r=-0.679), machine type and operator’s monthly income (r=-0.667) and lastly machine type and machine proceeding speed (r=-0.495).

Factor analysis was applied in order to ascertain the factor groups affecting the physiological workload of operators in loading operations in forestry (Table 1). Following the analysis of all the measurable variables (59 variables) 13 factor groups were formed. As a result of the rotation using varimax method, 89.51 % of the total variance could be explained with 13 factors cumulatively. In other words, nearly 90 % of workload can be measured with these 13 basic factors. The rest 10 % depends on other factors which can’t be measured or considered to be fixed.

Table 1 Rotation sums of squared factor loadings[*].

Factor No	Total	Variance (%)	Cumulative (%)
1	7.308	13.050	13.050
2	7.138	12.747	25.797
3	5.687	10.156	35.952
4	5.387	9.620	45.572
5	3.436	6.135	51.707
6	3.249	5.801	57.509
7	2.939	5.248	62.756
8	2.874	5.132	67.888
9	2.813	5.023	72.911
10	2.742	4.897	77.807
11	2.540	4.536	82.343
12	2.204	3.936	86.279
13	1.808	3.228	89.508

[*] Extraction Method: Principal Component Analysis.

In the interpretation of the factors, factor loads higher than 0.50 as the absolute value were taken into account. As the basis of interpretations, variables having the highest factor load were chosen for a true representation of the common feature of the factor. Thus, each of the chosen variables represented a different dimension of workload. As a result of the factor analysis, each of the factor groups was given a name using the values of the most significant variable.

Factor 1: Bodyweight; This factor is named “bodyweight” due to the fact that it consists of variables regarding the bodyweight among which significant correlations were found. The increase in weight, diameter and perimeter dimensions has a positive on the factor. Variables having the highest values are bodyweight (0.911), skinfold between the stomach and the rib (amount of fat) (0.857) and the skinfold under the omoplate (0.839).

Factor 2: Machine Technology and Noise; Since the group is composed of variables the majority of which are concerned with the development level of loading machines, it is named as above. That the machine has a cabin and air conditioning affects the factor positively, however, using tractors on which loading equipment is mounted instead of original loading machines and the noise level transmitted to operator affects the factor negatively. The highest variable values are noise level (-0.917), original machine and having a cabin (0.909).

Factor 3: Anthropometric lengths; It is given this name since it is mainly concerned with the values of the anthropometric dimensions of the body. Operator seat-body compatibility and stature, sitting height, hip width, knee height, the values of gripping level while sitting, which are all important for the posture in the tractor have a positive effect on the factor. Variables having the highest values are stature (0.912), sitting height (0.862) and hip width (0.751).

Factor 4: Vibration; This group is called “vibration” due to the fact that the majority of the variables consist of the ones regarding the whole body vibration transmitted to the operator from loading machines. Total rms acceleration values in the direction of z-axis, y-axis and x-axis have a positive effect on the factor. The highest variable values are total (0.965) and in the direction of z-axis (0.904) rms acceleration values of whole body vibration.

The other factors are named respectively; Factor 5: Work technique, Factor 6: The length of the operator’s arm, Factor 7: Climate factors, Factor 8: Social position, Factor 9: The surface of the terrain, Factor 10: Machine use duration, Factor 11: Motivation, Factor 12: Smoking and Factor 13: Machine Proceeding Speed.

The factors affecting the physiological workload of the loading machine operators while they are working are given in Figure 1.

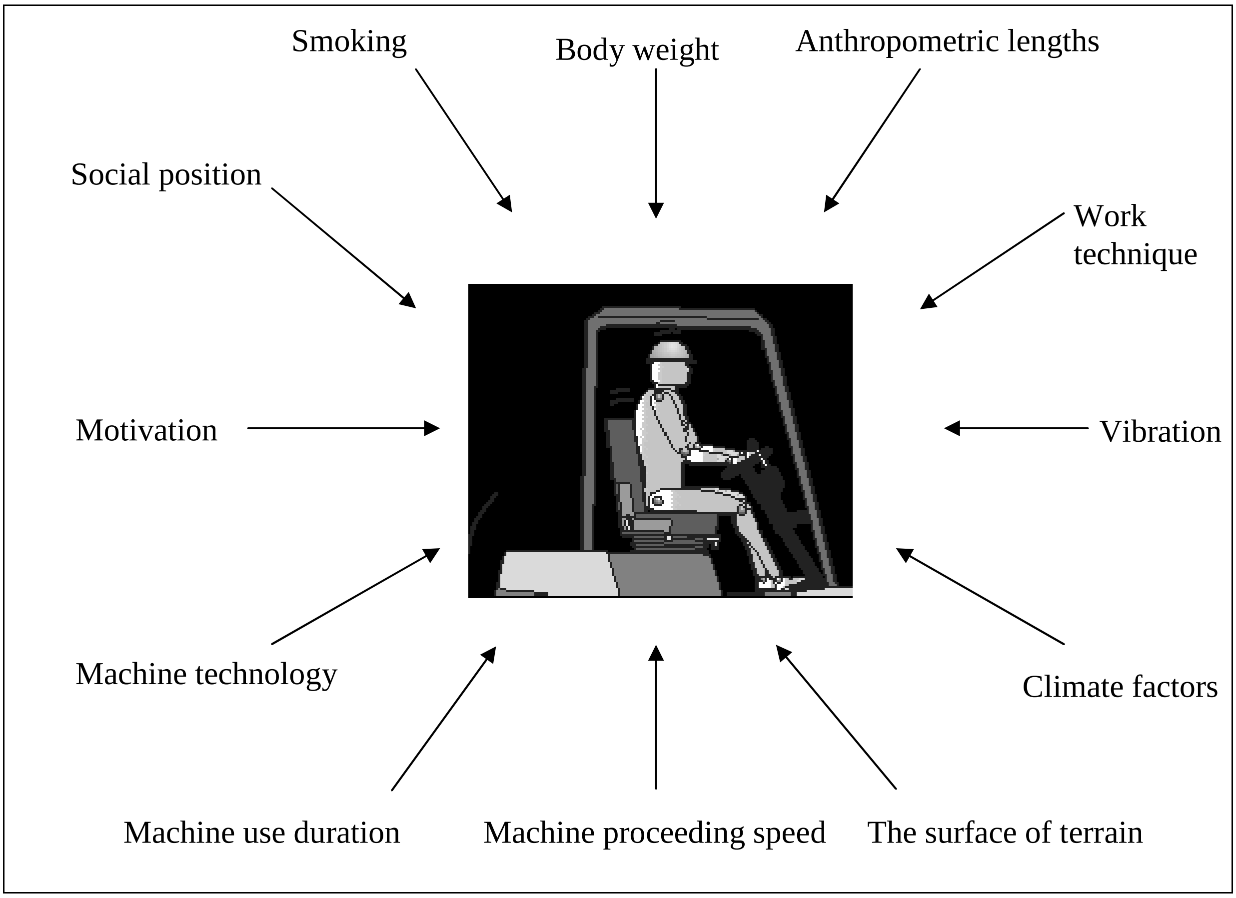

Figure 1 Factors effective on physiological workload of operators.

DISCUSSION

It was determined that the average physiological workload value (HRR %) of the operators while working with loading machines was 49 % and it was classified under the "medium difficult work" category the percentages of which were between 38-78 %. The characteristics of "medium difficult work" group are that energy consumption is between 2.5-5 kcal and heartbeat per minute is between 90-100. Although forest harvesting operations are usually considered "very difficult work" by ILO, it was found out in this study that loading operations with machines could be classified under "medium difficult work" group. When previous studies on physiological workload are evaluated (Abeli and Malisa, 1994; Kirk and Sullman, 2001); Shemwetta et al., 2002), it is understood that physiological workload value varies depending on the type of the work first and the difficulty level of it.

As a result of the correlation analysis carried out among all the variables affecting physiological workload, high correlations were found between anthropometric dimensions such as stature and sitting height; values regarding the machine such as machine type and cabin condition and values concerning the body fat ratio such as bodyweight and skinfold.

In this study, it was found that the factors such as bodyweight, machine technology and noise, anthropometric dimensions, vibration, work technique, operator's arm length, climate factors, social situation, ground surface, seat use duration, motivation, smoking and machine proceeding speed had an effect on physiological workload. Bridger (1995) classified the factors generally affecting the physiological workload under two groups; *personal factors* (age, bodyweight, sex, alcohol and cigarette consumption, active lifestyle, training diet and motivation) and *environmental factors* (atmosphere pollution, quality of the air, ventilation, altitude, noise, and extreme temperature). Kroemer et al. (1999) suggested that the factors affecting the physiological workload were age, sex, body dimensions, health training, being active, character, motivation, climate and altitude. Factors affecting the physiological workload such as bodyweight, anthropometric dimensions, climate factors and motivation that were put forward in past studies are consistent with the factors found in this study. Moreover, in addition to the general factors, variables such as machine proceeding speed and ground surface which are directly related with loading operations were found to have affected physiological workload.

CONCLUSIONS

Ergonomic criteria should be taken into consideration so that loading operations with machines can be performed more healthily, safely and productively in terms of operators. Machines used in loading and stacking operations and having static and dynamic defects should be renewed and using original loading machines instead of tractors on which loading equipment is mounted should be encouraged and supported. While choosing the loading machines, it should be paid attention whether the operator control area in the machine complies with the anthropometric dimensions of operators or not. In order to minimize the noise transmitted to the operator, the use of tractors having an original cabin should be ensured. While choosing the location of the forest depots, terrains which are flat and having a slope should be avoided and the roughness of the ground should be reduced by covering the ground of existing depots with stabilized materials. Anthropometric features and important ergonomic factors like noise and vibration which affect the physiological workload of operators should be evaluated constantly and regularly and loading operations should be performed productively.

REFERENCES

- Abeli W.S., E.J. Malisa (1994) Productivity and workload when cutting with peg and raker toothed croscut saws. International Seminar on Forest Operations under Mountainous Conditions. Harbin, P.R. of China, pp. 173-180.
- Acar H.H., Ö. Topalak (2001) Ormancılıkta kullanılan traktörlerin denetim aygıtlarının tip ve yerleşim açısından ergonomik nitelikleri üzerine bir araştırma (An ergonomic research on control device of tractors using forestry operations in respect of type and settlement), 8. Ulusal Ergonomi Kongresi, İzmir, s. 325-331.
- Astrand P., K. Rodahl, H.A. Dahl, S.B. Stromme (2003) Textbook of Work Physiology, physiological Bases of Exercise (forth edition). Human Kinetics, Canada, 650 p.
- Bridger R S (1995) Introduction to Ergonomics, St. Louis: McGraw-Hill Inc., 529 p.
- Gellerstedt S., R. Alnqvist, D.M. Attebrant, B.O. Wikström, J. Winkel (1999) Ergonomic Guidelines for Forest Machines, ISBN 91 7614 093 8, SkogForsk, Uppsala, Sweden, 85 p.
- Hirai T., Y. Kusaka, N. Suganuma, A. Seo, Y. Tobita (2006) Physical work load affects the maximum oxygen uptake., Industrial Health, 44: 250-257.
- Kirk M.P., M.J. M. Sullman (2001) Heart rate strain in cable hauler choker setter in New Zealand Logging Operations, Applied Ergonomics, 32: 389-398.
- Kirk M.P., R.J. Parker (1994) Physical demands of steep terrain forestry work in New Zealand. International Seminar on Forest Operations under Mountainous Conditions. Harbin, P.R. of China, pp. 196-204.
- Kroemer K., H. Kroemer, K. Kroemer-Elbert (1999) Ergonomics, How to Design for Ease and Efficiency, Prentice-Hall, Inc. New Jersey, 766 p.
- Lass J., H. Hinrikus, J. Kaik, K. Meigas (1997) Measurement of correlation between heart rate and physiological parameters variations, Proceedings in 19th International Conferences IEEE/EMBS,USA.
- Neitzel R., M. Yost (2002) Task-based Assessment of Occupational Vibration and Noise Exposures in Forestry Workers. AIHA Journal, 63: 617-627.

- Roja Z (2005) Measures to Overcome Health Problems of Latvian Road Builders Created by Ergonomical Risks, Doctorate Thesis, University of Latvia, Faculty of Chemistry, Institu of Occupational and Environmental Health, Riga.
- Shemwetta D., R. Ole-Meiludie, A.D. Silayo (2002) The physical workload of employees in logging and forest industries, Wood for Africa Forest Engineering Conference. South Africa.
- Tunay M., K Melemez, E.N. Dizdar (2006) Ormancılıkta kullanılan yükleme makinaları operatör koltuklarının antropometrik tasarımı (An anthropometric design of operator seat on the loading machine using forestry operations), ZKÜ, KTEF Teknoloji Dergisi, 9 (2): 137-144.
- Vitalis A (1987). The use of Heart Rate as the Main Predictor of the cost of work. In: Proceedings of the Inaugural conference of the NZ ergonomics Society, Auckland, pp. 168-181.
- Yıldırım M (1989) Ormancılık İş Bilgisi (Science of forestry work). İstanbul Üniversitesi Yayın No: 3555, Orman Fakültesi Yayın No: 404, İstanbul, 287 s.