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Comparison of Operators' Physical Responses Working with Two Different Machinery Combination during Hoeing Operation

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Abstract: Agricultural occupations require much physical efforts and are widely affected from environmental conditions. Therefore, using of farm machinery is indispensable. Different equipment and machinery have been used while performing agricultural operations. These equipment and machinery can be used to perform same operation. In this study, we compared operator's energy expenditure and means of heart beat values with working a rotary tiller mounted tractor and power tiller which have same working width. Energy expenditure values of operators were measured by SensWear Armband. Polar RS 800 heart rate transmitter watch was used to determine means of operators' heart beat values at operation of hoeing field. Measurements were taken for working this different machinery at three different forward speeds. Measurements of energy expenditure values were statistically analyzed using Minitab 15.0 and MSTAT. Based on the findings of these analyses; energy expenditure and means of operators' heart beat values were increased as increasing in forward speed. That is estimated working with a tractor-rotary tiller combination is caused less physical strain than working with a power tiller.
Key words: Tractor rotary tiller combination, power tiller, hoeing, energy expenditure, average heart beat value, human performance

INTRODUCTION

In Turkey, approximately 54.7% of whole agricultural enterprises have 0-49 da area. Average cultivated area of these enterprises is 20 da (Anonymous, 2006). These enterprises are generally suitable for orchards, vineyards and growing vegetables. Power tillers and tractor-rotary tiller combination can be used to cultivate orchards and vineyards.

Power tillers are generally used for land preparation in dry and wet land conditions. They are particularly suitable for small size fields. A power tiller operator walks behind the machine during the working period. Also the operator has to control forward movement and guide the machine while turning at headlands. Additionally environment conditions make the work harder. All of these factors cause fatigue on the operators (Tiwari and Gite, 2006).

Tractors which have been used for orchard and vineyard are constructed like having a narrow-track width. In recent years, orchard and vineyard tractors have become widespread in Turkey (Silleli, 2007).

The ability of workers to complete their work with less strain is one of main advantages in using agricultural machinery. Agricultural occupations are required much physical efforts and widely affected from environment conditions. Timeliness is an important factor to achieve an agricultural work. Therefore, using of farm machines is indispensable. Different types of equipment and machinery can be used to perform same work in agricultural operations. Users take into consideration their economic purchasing power, maintenance capability of machine or equipment. Recently they look for comfort when they choose a machine or equipment. For this reason, agricultural equipment and machines should be ease of use.

Many investigations were achieved about human performance and strain at working agricultural jobs until

today. Müller and Coetsee (2008) made a research to determine differences in energy expenditure and working efficiency of sugarcane cutters with regard to harvesting burnt and un-burnt sugarcane. The experiment was made by 15 male subjects. As a result of this work, they indicated that energy requirement for harvesting per kilogram un-burnt sugar cane is 2.13 kJ and for harvesting per kilogram burnt sugar cane is 1.51 kJ. Also they found that harvesting burnt cane required significantly more cutting strokes per minute than un-burnt cane. Tiwari and Gite (2006) compared four different work-rest schedules during operation with a power tiller. They measured heart beat values and body part discomfort grade. They indicated that working periods should not exceed 75 minutes, lunch breaks should be more than 45 minutes and rest pauses should be of 15 minutes during working with a power tiller.

In this study, operators' energy expenditure values and means of working heart beat values were compared for working with tractor-rotary tiller combination and power tiller. Findings of the research were assessed and then some suggestions were recommended for operators.

MATERIALS

Machines

For this research, hoeing operation was performed in a field with power tiller and tractor rotary tiller combination (Figure 1). A power tiller which has a 12 hp diesel engine was used. Its working width is 90 cm. Its weight is about 120 kg. Experiments were made at second forward speed.

Figure 1. Hoeing operation with tractor-rotary tiller combination and power tiller

Tractor which was used for the research has a 16hp diesel engine. A rotary-tiller mounted the tractor. Its working width is also 90 cm. Tractor-rotary tiller combination was operated at second low forward speed.

Subjects

Three well-acquainted male workers were selected randomly. They have enough field experience of operation with power tiller and tractor-rotary tiller combination. Physiological characteristics of these workers were given in Table 1.

Table 1. Physiological characteristics of the subjects

Operator	Age (years)	Height (cm)	Weight (kg)
A	27	175	70
B	23	190	91
C	26	175	77

They had no physical ailment. Before every experiment plot subjects, were asked to feel any pain or discomfort.

METHOD

Experiment procedure

This study was carried out in orchards which belong to Ankara University Faculty of Agriculture. The soil surface condition was dry and roughness. The weather during the experiment period was clear with the mean temperature and relative humidity varied between 15.0–22.0 ^{o}C and 22.3–47.7%, respectively.

In this research, operating depth was adjusted at 10 cm for operation with both machines. The trials were conducted at selected three forward speed levels; 1.6 km h^{-1}, 2.1 km h^{-1} and 2.6 km h^{-1}. To get these forward speeds, both machines were run through 100 meters in field and headway time was determined. Forward speeds were adjusted with hand throttle lever at tractor and gas clutch at power tiller.

The experiment was conducted at different time intervals of the day between 9:00 am and 5:30 pm. The trials were given in randomized order to minimize the effects of variation in environmental and soil factors. Each subjects had two rests for 10 minutes before starting trial and after hoeing operation. The subjects operated the machines for an hour. Each subject worked at three different forward speeds with two machines. Every trial pattern was repeated three times.

Determining energy expenditure

Energy consumption of workers is determined by indirect calorimeter methods in real working conditions.

Malavolti et al. (2007) assessed resting energy expenditure values of ninety nine subjects using a Sensor Medics Vmax metabolic cart with a ventilated canopy and with SenseWear armband. They found no significant difference in resting energy expenditure (REE) between SenseWear and Sensor Medics Vmax. They remarked that correlation between REE measured by SenseWear and Sensor Medics Vmax was high ($r=0.86$, $p<0.0001$).

In this study, because of ease of using at field research and transferring data from device to computer, a portable armband was used (Figure 2.).

Figure 2. Armband used to measuring energy expenditure values (Anonymous 2009a)

Energy expenditure values of subjects were measured SenseWear armband. The armband was placed on the upper right arm over the triceps muscles of each subject. It uses a 2-axis accelerometer, a heat flux sensor, a galvanic skin response sensor, a skin temperature sensor, and a near-body ambient temperature sensor to capture data. These data as well as body weight, height, handedness, and smoking status (smoker or non-smoker) are used to calculate energy expenditure values with SenseWear Professional 6.1 program which was provided by manufacturer.

We used the active energy expenditure values and physical activity duration to calculate average energy expenditure values of subjects in a minute (kcal min^{-1}). Interface of program which including type of using data was given in Figure3.

Determining mean of heart beat values

Heart beat values can be determined with different methods. In this research we used Polar RS 800 heart rate transmitter watch to determine means of operators' heart beat values (Figure 4).

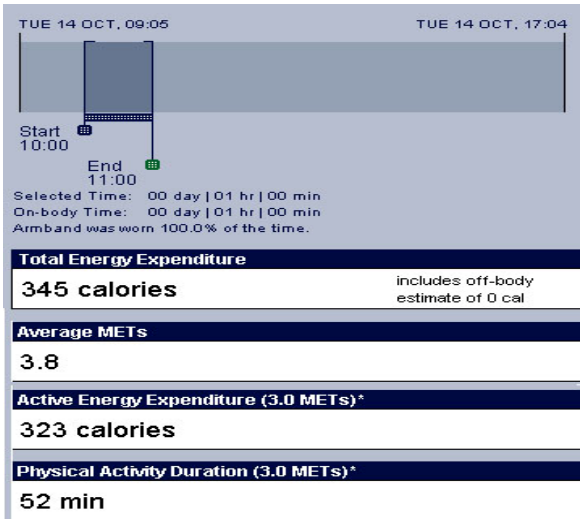

Figure 3. Interface of SenseWear Professional 6.1

Figure 4. Polar watch and chest strap (Anonymous 2009b)

Before taken measurements, moistened transmitter strap is positioned around chest, just below the chest muscles (Figure 5).

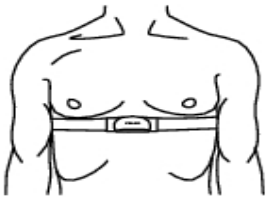

Figure 5. Position of transmitter strap (Anonymous 2009c)

The polar watch can be taken two measurements in a second. In this research, we took one measurement in a second. Measurements were taken through the working periods. We considered the data which were measured between tenth and sixtieth minutes because heart beat values of subjects

sustained to reach the steady state. Then measurements viewed as a list for every working period with Polar Pro Trainer 5.20.130 program. After that, measurements were transferred to Excel and means of heart beat values were calculated.

Data analysis

The observations energy expenditure and means of working heart beat values obtained from the experiments were analysed according to the factorial experiments in randomized block design considering the operators as blocks. There are two levels of type of machine are power tiller and tractor-rotary tiller combination; three levels of forward speed are 1.6 km h^{-1}, 2.1 km h^{-1} and 2.6 km h^{-1}.

When required, DUNCAN multiple comparative test was used to control whether there is a significant difference between factor levels. Results were indicated next to the required mean with form of letter representation.

The ANOVA was performed by using the MINITAB 15.1 statistical package. When required, MSTAT was used for DUNCAN test.

RESULTS and DISCUSSION

The results of ANOVA for energy expenditure of operators confirmed that levels of velocity and machine factors were significantly different from each other ($p<0.01$). Results of DUNCAN test were given next to the mean values as letter representation.

As understood from Table 2, energy expenditure values of operators are different from each other for operation at various forward speeds. Differences among the energy expenditure values for forward speed factor were found statistically significant ($p<0.01$). Energy expenditure values of operators were increased with increase in velocity.

Table 2. Differences among the energy expenditure values for forward speed factor

Velocity (km/h)	Energy expenditure values (kcal/min) $(\bar{x} \pm S_{\bar{x}})$	
1.6	3.250±0.257	c
2.1	3.583±0.249	b
2.6	4.049±0.260	a

(*Small letters were used to compare forward speed factors)

As seen at Table 3, operators' energy expenditure values are different for working with different machine types. Also this difference is important statistically ($p<0.01$). Energy expenditure values for working with power tiller are higher than working with tractor-rotary tiller combination.

Table 3. Differences among the energy expenditure values for machinery factor

Type of machine	Energy expenditure values (kcal/min) $(\bar{x} \pm S_{\bar{x}})$	
Tractor-rotary tiller	2,5904±0,0721	b
Power tiller	4,6644±0,0734	a

(*Small letters were used to compare factor of machine type)

As a result of analysis of variance for means of operators' working heart beat values, velocity*machine interaction were statistically significant ($p<0.01$). Results of DUNCAN test were given at Table 4.

Table 4. Interaction between type of operation and velocity factors

Velocity (km/h)	Type of machine: Power-tiller (hearth beat) $(\bar{x} \pm S_{\bar{x}})$		Type of machine: Tractor-rotary tiller (hearth beat) $(\bar{x} \pm S_{\bar{x}})$	
1.6	112,56±1,280	A c	82,333±0,726	B c
2.1	124,44±1,250	A b	88,000±0,645	B b
2.6	134,11±0,992	A a	92,444±0,530	B a

(*Small letters were used to compare velocity factors. **Capital letters were used to compare type of operation factors)

Means of operators' heart beat values are different for comparing type of operation. Also means of heart beat values are different from each other for working at different velocities. And these differences are significant statistically ($p<0.01$). Increasing velocity at working with both operation types is increased means of operators' working heart beat values. Means of working heart beat values for working with power tiller are higher than working with tractor-rotary tiller combination for all mentioned levels of velocity factor.

Both analyses showed that working with power tiller is caused more strain than working with tractor-

rotary tiller combination. Because operators must walk behind the power tiller and control the machine during hoeing operation. Also sharp turns at headlands and environment conditions are forced the operators. But, at working with tractor-rotary tiller combination operators try to follow a line to cultivate field smoothly. The most important difference between two types of operations is operators work sitting. Tewari et al. (2004) modified to enable operation in a seated position with a power tiller. They compared physiological effects of working seated position and standard design where the operator must walk behind the machine. They found that working at seated position caused less strain.

Working with a power tiller is in heavy work category. Means of energy expenditure values which belong to working with power tiller is higher than 4 kcal min^{-1}. This value could be accepted like a threshold to determine strain of working conditions (Dinçer, 1977).

CONCLUSIONS

The followings were concluded from this study:

- Working with tractor-rotary tiller combination has caused less strain than working with a power tiller.
- Energy expenditure values and means of heart beat values were increased with increase in velocity for both operation types.
- Working with a power tiller is in a heavy work category.

This study indicated that working with power tiller is causing fatigue to operators. According to this research pattern, if it is appropriate using tractor-rotary tiller combination can be recommended instead of power tiller during hoeing operation at 1.6 km h^{-1}. Also they should consider properties of enterprises such as purchasing power, repair and maintenance.

Future studies will be useful for farmers and researchers if includes aspect of agricultural management such as work efficiency, acquisition cost and maintenance cost.

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