

PHYSICAL WORKLOAD WHILE WORKING WITH HEDGING BILL AND BATTERY CUTTER IN TENDING OF PEDUNCULATE OAK

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Abstract

The main tool used in forest tending work is a hedging bill, a hand tool consisting of a hold and a blade sharpened on both sides. Working with the hedging bill is physically very tiring and takes place under difficult working conditions (high temperature, dense vegetation, insects). For purpose of humanizing the forest tending work, a tool that has not been yet used in Croatian forestry - the battery cutter in this case Stihl ASA 85 - has been tested. In this paper a comparison of hedging bill and battery cutter was made from an ergonomic aspect. Average and maximum heart rate of a worker when working with the two mentioned tools was taken as a relevant comparison factor. Measuring the heart rate during effective work time the physical workload of the worker was determined. Garmin Fenix 3HR has been used to measure heart rate in the conducted research. The results obtained show less physical workload of workers when working with battery cutter.

Keywords: *physical workload, hedging bill, battery cutter, forest tending, Croatia*

1. INTRODUCTION

In Croatian forestry forest tending is mostly done manually. The most frequently used tool is hedging bill. Due to delicacy of tending work (worker must pay attention on the present young trees of significant species) a semi-mechanized mowing can't be applied. Working procedure is that worker holds a hedging bill in one hand, and with the other hand he bends a tree for easier cutting. After cutting, the worker is pulling the tree from the crown zone and placing it at least one meter below the crowns of the pedunculate oak. If tending takes place in stands with slightly larger diameters, the worker must hold the hedging bill firmly with both hands to perform the cutting. Working with the hedging bill is physically very tiring and takes place under difficult working conditions (high temperature, dense vegetation, insects). Hedging bill as a tool certainly finds its application in stands where the diameters are small, and the presence of oak is poor. In such stands, the worker doesn't have to pay much attention to the existing young oak trees and does what the hedging bill is made for – mowing and trimming. Furthermore, when working with hedging bill in stands where undesired wooden species are of somewhat larger diameter, i.e. where more swings are needed to cut one tree, the worker receives strong strokes that are felt from the wrist to the shoulder joint. The frequent use of hedging

bill in such works leads to injury to worker and a decrease in the quality of his life. In terms of quality of work and productivity, it is also possible to notice the negative sides of the use of the hedging bill in the mentioned working conditions. From long-term perspective, replacing hedging bill in works of oak tending and partial mechanization of these works, the number of disabled workers resulting from the use of an inappropriate tool would be reduced. In Croatian forestry, most of the works are mechanized and the tendency is that manual works are also mechanized. Mechanization of works in forestry has a multiple positive effect on the physical workload of worker, its productivity and preservation of its health, the quality of the work done, and the satisfaction and motivation for work. Ergonomic research in forestry in Croatia is more intensely carried out in the 90s of the 20th century, where for estimating the physical workload in a dozen types of forestry works (Tomanić et al. 1990; Vondra et al. 1990; Martinić 1993; Martinić 1994; Vondra 1995) from practical reasons, methods based on pulse measurement were applied. Several authors state that cardiovascular load in pre-harvesting operations when using semi-mechanized tools rather than manual tools is significantly reduced (de Oliveira et al. 2014; Nutto et al. 2013). For purpose of humanizing the work of tending of the oak stands, a tool that has not been used in Croatian forestry, battery cutter, has been tested and compared to hedging bill by using average working heart rate to define physical workload. In orcharding battery cutter has been used for pruning trees for many years, and due to similar nature of the work in the tending of oak stands, the possibility of their application in forestry has been observed.

2. MATERIALS AND METHODS

2.1 Research area

The research was conducted in 10 years old state forest managed by Forest Administration Vinkovci, Forest Office Vinkovci. Main commercial tree species in this part of Croatia is pedunculate oak (*Quercus robur* L.). In early life of pedunculate oak it is necessary to perform tending work to assure, among many other features, high quality wood product in future. Young forests in Forest Administration Vinkovci are divided by geometrical network of breeding paths. Segments of divided forest have 5 m x 35 m dimensions, and area of approximately 175 m². These segments were main unit of conducted measurements and all measuring is made on the segment level. Terrain was horizontal. Observed forest segments were all next to each other to avoid major variability. Air temperature during conducted measurements was between 15 °C and 25 °C.

2.2 Research objects

Worker was a 41 years old male with body mass of 105 kg, and height of 180 cm. At the time of research worker had 16 years of working experience in forestry. For conventional tending method worker was using standard issued hedging bill (figure 1 - left) with a mass of 1,5 kg and a length of 1,15 m. For new method Stihl ASA 85 battery cutter with a mass of 0,98 kg and AP 300 backpack battery with a mass of 1,7 kg (figure 1 – right) was used.



Figure 1: Hedging bill (left), battery cutter (right)

2.3 Research instruments and methods

Data was collected during tending of four segments using conventional tool (hedging bill) and four segments using new tool (battery cutter). During tending of specific forest segment with either of mentioned tools, worker was recorded with action camera type SJ4000. Video recording was performed to obtain effective worktime, and also to count number of swings with hedging bill per one forest segment. The number of swings was obtained by viewing recorded video files. Number of cuts with battery cutter was obtained via built-in counter on the control unit. Number of swings/cuts is relevant factor of forest segment variability. More swings/cuts mean that more unwanted tree species are present on the observed forest segment, and consequently more tending work is necessary. Swings and cuts are not to be mixed, as it takes significantly more swings with hedging bill than cuts with battery cutter to tend one forest segment. Obtained data is sorted out in MS Excel 2016. To evaluate and compare physical workload of worker while working with hedging bill and battery cutter, a heart rate method was used. Worker was equipped with Garmin Fenix 3HR heart rate monitor, and his heart rate was recorded during effective worktime. After tending one forest segment worker would take one longer pause to lower his heart rate to levels before any work. In practice, during tending work, it is common that worker is working until he finishes one forest segment before resting. Average and maximum heart rate during effective work in addition to heart rate dynamics were taken as relevant parameters. Heart rate monitor is designed in form of a wristwatch and it didn't interfere with worker's movements during tending. The physical workload assessment was based on the methodology proposed by Apud (1999). Before measuring heart rate, it is necessary to inscribe worker's age, sex, body mass and height, and wrist where heart rate meter is placed (left or right). Recorded heart rate data is downloaded via Garmin Connect user's interface and sorted out in MS Excel 2016.

Table 1: Classification of physical workload according to the average working heart rate

Physical workload	Average working heart rate [bpm]
Very light	< 75
Light	75 - 100
Moderately heavy	100 – 125
Heavy	125 – 150
Very heavy	150 – 175
Extremely heavy	> 175

Source: Taken from Apud E., 1999 [1]

3. RESULTS AND DISSCUSION

Research results are displayed in table 3 where physical workload in every forest segment (Seg) is determined by using average working heart rate. Although all forest segments were next to each other, some of them had more oak trees, and some of them more trees of unwanted species. Effective work time, number of cuts/swings and cuts/swings per minute represent factors of forest segments variability. However, because neither cut with battery cutter nor swing with hedging bill represent one cut down tree, variability of forest segments tended with different tools can't be compared. With mentioned factors, only variability of forest segments tended with the same tool can be compared.

Table 2: Research results

Battery cutter						
Seg	Effective work time [hh:mm:ss]	N cuts	Cuts/min	Avg HR [bpm]	Max HR [bpm]	Physical workload
1	00:40:49	762	18,7	120	157	Moderately heavy
2	00:36:08	748	20,7	116	147	Moderately heavy
3	00:30:00	576	19,2	121	143	Moderately heavy
4	00:42:06	830	19,7	126	145	Heavy
Avg	00:41:15	729	19,6	121	148	Moderately heavy
Hedging bill						
Seg	Effective work time [hh:mm:ss]	N swings	Swings/min	Avg HR [bpm]	Max HR [bpm]	Physical workload
1	1:11:21	1803	25,3	131	169	Heavy
2	1:04:23	1650	25,6	127	162	Heavy
3	1:02:50	1632	26	114	166	Moderately heavy
4	00:48:33	989	20,4	122	148	Moderately heavy
Avg	1:01:44	1518,5	24,3	124	161	Moderately heavy

Working with hedging bill lasted on average 20 minutes and 29 seconds longer than working with battery cutter, and it takes more than twice as many swings with hedging bill to tend one forest segment in comparison to cuts with battery cutter. Results also show that worker is doing more swings than cuts per minute. Swinging the hedging bill is physically exhausting and requires more workers energy than cutting with battery cutter. Consequently, higher average and maximum heart rate was recorded when worker was working with hedging bill.



Figure 2: Heart rate dynamics (battery cutter – 3 segments)

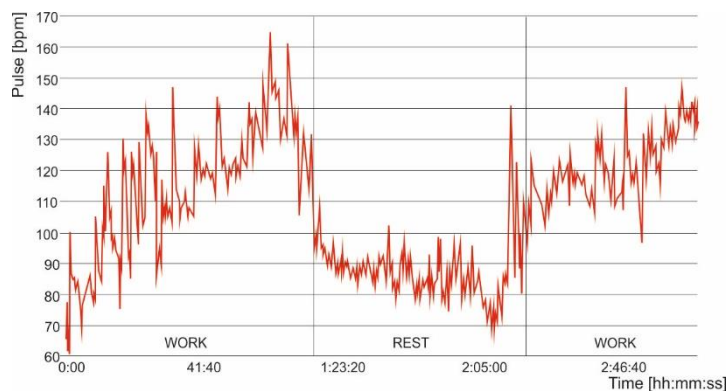


Figure 3: Heart rate dynamics (hedging bill - 2 segments)

The biggest difference is in the maximum heart rate, while the average heart rates are quite similar. Similarity of average heart rates can be explained with worker's working pace. While working with battery cutter the working pace was even throughout one forest segment. However, while working with hedging bill, worker was reaching higher heart rate faster, and had to intentionally slow down to lower his heart rate and make work more comfortable (Figure 3, second segment). This can also be seen in figure 2 and figure 3 where is evidently that the highest peaks are reached while working with hedging bill, rather than battery cutter. Regarding physical workload, on average working with both tools was classified as moderately heavy. Although, work in half of segments tended with hedging bill is classified as heavy and average value is just below the heavy class. Influence of effective work time duration is also notable. In both cases (hedging bill and

battery cutter) the highest average pulses were recorded in forest segments with the longest effective work time.

4. CONCLUSION

Recorded heart rates point to higher physical workload when working with hedging bill. Worker is working longer and at the quicker pace when working with hedging bill. In addition to lower heart rate when working with a battery cutter, worker is also more productive compared to working with hedging bill. While the average heart rate is similar when using both tools, there is a significant difference in maximum heart rate and effective work time between two observed tools. Results confirm that semi-mechanized tools can reduce physical workload and improve productivity in pre-harvesting operations. In this example humanization of work is mostly reflected in lower time exposures to physical workload.

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