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ORIGINAL ARTICLE

Comparison of farmers workload by manual and mechanical tasks on family farms

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Abstract

The aim of this study was to compare the workload between tasks undertaken manually and those with the assistance of mechanical devices. The results indicate that the workload during the tasks assisted by mechanisation was usually very low or relatively low. Statistical analysis showed the impact of the way of the work performance on the workload. However, the results also indicate that the workload is not evenly distributed: the effort relating to the working tasks is larger in relation to the work of women than men. The need for mechanisation of the tasks performed by women is higher than that for the mechanisation of tasks performed by men. The type of work performance (manual, or technically assisted) did not clearly show significant differences in the workload. This surprising result indicates that the technical devices used on many farms are still far from perfect. It is concluded that assisting work with mechanical devices reduces the workload of farmers, but the way of work performance (manual or mechanical) was not statistically significant.

Key words

workload, mechanisation of work, farmers, heart rate reserve index, family farms

INTRODUCTION

Human work can be assisted with tools, devices or machinery. The technical equipment on farms therefore has a significant impact on the work performed, which is reflected in the workload of a man who replaces the work of his muscles with the work of technical devices. Mechanisation allows work to be performed more efficiently, i.e. a bigger amount of work (number of hectares cultivated, transported tons of weight, cows milked) can be performed within a shorter period of time compared to the same work performed manually [1]. For example, manual milking compared to milking by the pipeline system or the parlour system (bigger number of litres of milk or cows milked within one hour), or the manual harvesting of grain compared to using a combine harvester (bigger amount of harvested grain or of hectares of mown grain, e.g. for harvesting of sheaves of wheat from one hectare per hour, 25–30 people are needed, the binder allows such a harvest to be undertaken using only 1–2 people, and the combine harvester in the 1970s – combining the cutting with the grain threshing – enabled the harvesting of grain from an area of 2 hectares in 1 hour [2], while the contemporary, modern combine harvesters can harvest even 6–8 hectares per hour (675.84 tonnes per 8 hours = an average of 84.48 tonnes per one hour) [3]. Of course, each machine is operated by a man. The increase in the productivity of human labour by assisting or replacing with mechanisation also has ergonomic implications. The aim of mechanisation is not only a substitution of human labour with materialised labour [4], but the creation of the most favourable work conditions for a man [2].

One of the methods – quite commonly used in research practice is to measure heart rate as an index of physical workload [5, 6, 7, 8, 9, 10, 11, 12, 13]. Despite the drawbacks of this method (e.g. impact of the examined person's emotional state, or the conditions under which the study is made on the obtained results), it is used in studies conducted in actual (not laboratory) work conditions.

Studies of the human workload assisted by mechanisation were carried out in agriculture, for example, during cow milking using different milking systems – the can, pipeline and parlour systems [6]. The average heart rate of the examined persons during milking with the can system was the highest (92.8 beats/min), followed by the parlour system (90.1 beats/min) and the pipeline system (86.5 beats/min) [6]. In contrast, the values of index of use of the heart rate reserve HRR (explanation of the calculation and interpretation of the index are provided later in the article) were, respectively, 28% during milking using the can system (in the morning), 32% during milking with the pipeline system, and 11% using the parlour system [6].

Work in agriculture is divided into activities relating to crop and animal production, as well as housework relating, for example, to the preparation of meals for the farmer's family, etc. Housework can also be assisted by mechanical devices, such as dishwashers, washing machines, or vacuum cleaners. From a comparison of the workload during the operation of four types of dishwashers, it becomes evident that the heart rate ranged from 100–102 beats per minute [14], while during manual dishwashing there was a wider range, from 94–110 beats per minute [15, 16].

Taking all above into account, the mechanical support of work might minimize the workload of farmers and reduce the load on the cardiovascular system. However, there is a need to compare the loads during manual and mechanically assisted activities.

The aim of the presented study was to compare the workload between the tasks undertaken manually and those with the assistance of mechanical devices.

MATERIALS AND METHOD

Subjects. The study comprised 234 farmers (150 women and 84 men) aged 18–60 (Tab. 1), whose work experience ranged from several months to more than 30 years (Tab. 2).

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Table 1. The age range of the examined population

Age range [years]	Number of subjects	
	Female	Male
< 20	1	3
20–30	51	29
31–40	26	15
41–50	43	20
51–60	29	17
Total	150	84

Table 2. Work experience on the farm relating to women and men

Work experience [years]	Number of subjects	
	Female	Male
< 1	0	0
1–5	5	7
5–10	32	13
11–15	17	13
16–20	15	8
21–25	9	8
26–30	27	9
> 30	45	26
Total	150	84

Farm characteristics. The studies were conducted on 50 farms (agricultural farms – including horticultural farms – and farm households). Work on the farm is associated not only with the performance of typical agricultural activities (crop and animal production), but also with housework or bringing up children, especially in the case of women. This is the reason the study also included the housework load.

The area of agricultural land of the farms was in the range 1.08–360 ha (Tab. 3). The majority of farms (n = 34) had an area of agricultural land amounting to more than 1.95 hectares, i.e. the average area of individual farms in Małopolska (Lesser Poland) [17]. Arable land constituted more than a half of the agricultural land area, except for horticultural farms (14 farms) and one farm of laying hens. Typical arable land accounted for more than 90% of the farm area. Farms with a horticultural production profile had greenhouses with an area ranging from 310–14,000m^2 (Tab. 4).

Animals were bred on 33 farms, i.e. in 66% of the whole selected group. Dairy cattle predominated on two farms, pigs on three, and poultry on 28 farms. Comparison of the collected characteristics of the farms with the statistical data [17] indicates that these farms were bigger than the average farms in Małopolska. The stocking density on the examined farms amounted to: cattle from 1–400 head, pigs from 1–110 head, poultry from 10–25,000 head.

Table 3. The total area of typically agricultural farms

Area of agricultural farms [ha]	Number of farms
>5	9
5.01–10	12
10.01–15	11
15.01–20	1
>20	2
Total	35

Table 4. The total area of horticultural farms (greenhouses)

Area of horticultural farms [m^2]	Number of farms
>500	6
501–1000	6
<1000	2
Total	14

Technical farm equipment included the basic tools and machinery for crop and animal production. The majority of farms (n = 36) had their own tractors (the other farms were small horticultural farms, and a large farm of lying hens that bought the feed for poultry wholesale). Four farms had a combine (combine harvester on 3 farms with an area of 15 ha, 19.1 ha and 171 ha, and a potato harvester on a farm with an area of 10 ha), and three farms used the external services of field works performance.

'Photography' of work day. The "photography" of a work day (work day observation) means that persons involved in the study kept diaries in which they recorded activities during the day, and the duration of each activity. Taylor [18] applied this kind of research for the first time, and today it is called the 'photography of a work day' or the work day observation. The disadvantage of this method is that it requires very time-consuming, but this difficulty is solved by the snapshot survey of work time. This is a statistical method was developed by Tippet [19] and is called 'the method of snapshot observation' This method first found its application on a large scale in the textile industry, for which it was developed, after which it began to spread quickly into other industries [18]. The 'photography' of the work day method was used in the presented study. The data collected by this method allow: a) specification of the type of work undertaken on the farm; b) time of work performance; c) time variability of work performance in each month during the year.

Measurements of heart rate. The heart rate was measured and registered by wireless apparatus Polar Electro Sport Tester (Polar Electronics, Kemple, Finland). The device consists of a band (in which two transmitters are mounted) placed around the chest, and a recorder placed on the wrist of the person examined. The heart rate was the indicator of the workload. Despite the disadvantages of this method (external influences, emotions, alcoholic beverages or coffee consumed), it is a method which is relatively easy to use in production conditions [6, 13, 20, 21, 22, 23]. This advantage is particularly important in agriculture where the variation in types of works is very large, and was decisive in its use in the research.

Heart Rate Reserve (HRR) index. [22, 24, 25, 26, 27] Was calculated according to the following formula [1]:

$$HRR = \frac{WHR - RHR}{MHR - RHR} \cdot 100[\%]$$

where:
WHR – average heart rate during work [beats/min]
RHR – resting heart rate [beats/min]
MHR – maximum heart rate for examined person [beats/min]

Workload was assessed based on the scale shown in Table 5. The authors considered short-lasting activities to be those which did not exceed 30 minutes, while long-lasting activities were those with a duration exceeded 30 minutes.

Table 5. The workload classification on the basis of the Heart Rate Reserve Index [28]

The workload classification	HRR [%]	
	Short-lasting activities	Long-lasting activities
Very low	> 25	> 15
Relatively low	26–35	16–25
Medium	36–50	26–35
High, acceptable only for persons with the healthy cardiovascular system	51–65	36–50
Conditionally acceptable	66–80	51–65
Not acceptable	< 80	< 65

RESULTS

Workload of farmers during activities relating to mechanisation and works undertaken manually. Work undertaken by farmers on a farm – crop and animal production, or in the household – were divided into two categories of activities performed manually (Fig. 1) and performed using mechanical tools (Fig. 2).

Figure 1. Work undertaken manually (feeding pigs).

Figure 2. Work undertaken using mechanical devices (from the left: mechanical cow milking, egg grading control).

Results of the study, i.e. the share of manual work and those assisted by mechanical devices during work performance by farmers (women and men) on the farm, divided into crop and animal production, as well as household tasks, are described in Table 6.

Table 6. The percentage share of manual works and those aided with mechanisation

Type of work	Crop production		Animal production		Household
	Female	Male	Female	Male	Female
Manual	90.5	75.2	87.0	73.8	86.7
Mechanical	9.5	24.8	13.0	26.2	13.3

Assessment of manual and mechanical workload for all examined activities of women and men, with the division into work relating to crop and animal production, as well as household tasks, is presented in Table 7.

Table 7. Assessment structure of the workload of farmers with manual works and those aided with mechanisation (%)

Workload	Crop production				Animal production				Household	
	Female		Male		Female		Male		Female	
	1	2	1	2	1	2	1	2	1	2
A	32	13	14	10	25	–	5	12	18	16
B	26	39	28	40	30	56	34	36	43	43
C	25	17	31	30	25	22	38	24	30	30
D	23	30	22	20	17	22	17	18	9	9
E	2	–	2	–	3	–	5	6	–	2
F	–	–	2	–	–	–	–	3	–	–

Statistical analyse. A three-factor analysis of variance (ANOVA – Analysis of Variance) of an index of use of heart rate reserve (HRR), according to the following factors:

1) type of work – crop production, animal production, household works, during which the work was undertaken;
2) gender of person performing the work;
3) mechanical or manual method of work performance (type of work).

The results are presented in Table 8. This analysis was intended to prove that the index values for the use of heart rate reserve (HRR) during work in agriculture are dependent on the above-mentioned three factors.

Table 8. Three-factor analysis of variance of dependence of HRR on the type of work, gender and work performance.

Variance source	Sum of squares	Number of freedom degrees	Average square	Value of the test statistics F (Fisher-Snedecor)	Calculated F-statistic significance level
Main effect (including)	4205.874	4	1051.469	10.325	0.000
Work type	2177.346	2	1088.673	10.691	0.000
Gender	987.158	1	987.158	9.694	0.002
Work performance (mechanical, manual)	240.766	1	240.766	2.364	0.124
Explained variance	4205.874	4	1051.469	10.325	0.000
The rest (mistake)	94400.868	927	101.835	-	-
Total	98606.742	931	105.915	-	-

DISCUSSION

Analysis of the mechanisation impact, i.e. substitution (replacement) of manual work with work by mechanical machinery, requires the specification of criteria for the division into manual and mechanical work. It should also be noted that even mechanised work (and even automated

work) contain in themselves a higher or lower share of manual activities. Example activities performed manually and recorded during the presented study include: plucking potato shoots (in storage before planting), plucking leaves from carrots, manual cow milking, manure removal, dish- and window-washing. Example activities performed by means of mechanical tools include: planting of cabbages with semi-automatic planters, irrigation system operation in plastic tunnels, cow milking using the parlour system, egg sorting control by using an automatic sorting machine, or vacuuming with a vacuum cleaner.

Quantitative analysis of activities in crop production shows that the majority (90.5%) of all operations were performed manually (Tab. 6). Only 9.5% of activities were performed by women using technical devices. For comparison, in crop production, the men performed more activities (24.8%) using mechanised equipment (Tab. 6). Mechanical work in crop production performed by women included: drip irrigation system operation in a plastic tunnel or greenhouse, planting of cabbages and cauliflowers by means of a semi-automatic planter, potato sorting operation, grass mowing with an electric or petrol-driven lawnmower, mechanical plucking of leaves from beets, weighing onions on electronic scales, spraying vegetables with a sprayer attached to a tractor, or fertilisation of plants with a fertiliser spreader attached to a tractor.

The results obtained indicate that in crop production there are still many activities performed manually, without using any technical devices. Preparing vegetables for sale, cargo handling, watering and weeding plants are usually performed manually, although mechanisation of these activities is technically possible. Economic barriers are generally the reason for not introducing such mechanisation. Note that the presented study was carried out in the southern area of Poland, where many farms conduct their manufacturing activities with such technologies (tools, machines) that were the subject of the study. The results obtained can therefore be generalised with a high degree of probability and transposed to other farms (i.e. the workload of the staff employed).

A similar quantitative structure of activities performed by women also appeared in animal production, i.e. 87.0% of activities performed manually, and 13.0% by using technical devices (Tab. 6). Typical activities performed manually included: feeding animals, watering animals using buckets, bedding and manual cow milking. Work undertaken by using mechanical devices included: cow milking using the parlour system and automatic egg sorting operation.

A slightly larger proportion, i.e. 13.3% of measurement of activities in this category, was found in the case of mechanised work in the household (Tab. 6). Activities performed manually constituted 86.7%. Examples of mechanised work included: operation of an automatic washing machine for washing clothes, vacuuming carpets with a vacuum cleaner, sewing clothes with a sewing machine, and washing dishes by using an automatic dishwasher (dishwasher operation). Examples of manual work performed by women in the household were such activities as cooking, preparing breakfast, washing floors, washing windows, hand washing and caring for a child/children.

Comparing the proportion of mechanised works performed by men, it was observed that, in both crop and animal production, the activities were more often mechanised than in the case of women (Tab. 6). For example, mechanised work relating to crop production (24.8% of measurements of activities of this category) included such activities as: riding on a tractor, irrigation system operation in a plastic tunnel or greenhouse, washing vegetables (celery, carrots) in a washer, transport of beets from the field (tractor with trailer), and harrowing fields. Manual work in crop production performed by men included such activities as: quilting plants, collection of vegetables in greenhouses, putting cabbage in bags, loading bags (20 kg) with vegetables into a car.

Mechanised work in animal production (Tab. 6) performed by men accounted for 26.2%. They included such activities as milking cows using the parlour system, feed preparation for animal by a crushing machine, and hay bale transport by tractor. Manual work in animal production performed by men included: sweeping the animal house floor, providing feed for animals with forks, animal watering with buckets, and manual removal of manure.

The workload of women in crop production with activities performed manually was very or relatively little (Tab. 7) in almost half of the cases (58%). A load acceptable only for healthy people, or only conditionally acceptable, included 15% of cases out of 220 analysed records of activity in the given category. Thus, although a lot of work is performed manually in crop production, the body workload caused by this work is generally little.

Relationships quite similar to those described above occur also during work in animal production and in the household (Tab. 7). Low and relatively low loads occurred in 55% of cases of work in animal production and 61% of work in the household. Yet 20% of manual work in animal production caused a load acceptable only for persons with a healthy cardiovascular system, or was conditionally acceptable. In the household, 9% of the activities performed manually caused a load acceptable only for healthy people.

Contrary to stereotype intuitive beliefs, the use of mechanical tools does not eliminate the body load at a level acceptable only for healthy people, or is conditionally acceptable. In crop and animal production the loads concerned 30% and 22%, respectively, of all measurements in this category. Therefore, the mechanical operation of devices required the use of force, and although it usually improved work comfort, in many cases it caused a load similar to that of manual work.

The proportion of the amount of body load was very low and relatively low during manual activities, and with using mechanical devices it was similar in crop and animal production, and in the household. A similar conclusion stems from a comparison of the loads belonging to the average categories.

From comparison of workloads of women and men (Tab. 7) relating to crop and animal production, there was the general trend that the proportion of activities causing average load, acceptable for a healthy body and acceptable only conditionally, was higher in relation to men.

In fact, work that required a huge effort was undertaken by men on the agricultural farms. A similar observation concerned the activities performed with using mechanical devices. In animal production, 51% of the measurement of activities causing average loads, acceptable for healthy people and conditionally acceptable, were undertaken by men, and 44% by women (Tab. 7). A similar situation was observed in the case of crop production. Mechanised activities (Tab. 7) causing average loads, acceptable for healthy people and conditionally acceptable, amounted to 50% for men and 47% for women.

The presented study shows that the technical equipment on farms decreased the workload of women and men when the results obtained are compared with the results published several years ago. The studies conducted in the 1970s and 1980s showed that the proportion of work imposing a significant load on female farmers was relatively high [29, 30]. Housework in agricultural households was performed exclusively by women. The results obtained show that the workload during performing activities aided with mechanisation was mostly very or relatively low, the exception being the small proportion of work performed by men in animal production (Tab. 7).

Statistical analysis. At the declared level of significance of 0.05, there were two significant factors, i.e. the type of work (very important, calculated level of significance at a level of 0.000) and gender (calculated level of significance 0.002). The method of conducting the study was statistically insignificant.

Therefore, statistical analysis showed that the way of performing the work (with or without the assistance of devices) has an impact on the workload. This result confirms the intuitive predictions and somewhat confirms the aim of the use of mechanisation. However, the results indicate that the workload is not evenly distributed: the effort relating to the working activities is larger in relation to the work of women than men. The need for mechanisation of work traditionally performed by women appears somehow higher than the mechanisation of work performed by men. The type of work performance (manually or assisted by machinery) did not show clearly significant differences in the workload. This paradoxically unexpected result indicates that technical devices on many farms are still far from perfect. This applies in particular to the tools and devices of simple design, therefore the cheap ones.

CONCLUSIONS

The results of the presented study show that assisting work with mechanical devices reduces the workload of farmers, but the method of work performance (manual or mechanical) was not statistically significant. This may be due to the faster pace during work with mechanical devices. The workload by mechanised activities compared to the activities performed manually was lower and most often assessed as very or relatively low.

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