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Validation of automated detection of physical and mental stress during work in a Hühnermobil 225

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Abstract

Introduction. The effects of the use of mobile henhouses and their equipment on the physical and mental stress of farmers in the organic egg production, and the reliability of the sensor-based detection of these in work processes are insufficiently known. There are neither measurement results nor key figures, according to operation and gender especially, available in the literature.
Objective. The aim of this case study is to quantify the physical and mental stress of work processes on the basis of heart rate and the Baevsky Stress Index, as measured by the ECG- and activity sensor Movisens®, which is used mainly in the sports and rehabilitation sectors. To analyse the impact, daily routine work was divided into operations and the data collected for this purpose analysed descriptively and analytically.
Conclusions. In summary, it can be concluded that measurement technology has the potential to capture the activity-related exceedances of the endurance limit of the work severity by means of the heart rate reliably, to identify risk areas of employment and to quantify stress situations. The accuracy and reliability of data acquisition with Movisens® should be validated by a larger sample size and further measurements. In particular, the algorithm for calculating the data to quantify the mental and physical stress without movement needs to be improved significantly through further development.

Key words
workload, heart rate, stress

INTRODUCTION AND OBJECTIVES

Organic egg production is experiencing a steady growth in Austria and Germany. Over the past decade, mobile henhouses, such as the Hühnermobil 225, have been developed. Mobile henhouses are used in free-range productions with a small brood size. The advantages of this system are low construction costs and good hygienic conditions by moving the mobile pen.

Figure 1. Hühnermobil 225 (photograph: Trieb, 2013)

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Despite extensive mechanisation of work processes, livestock farming always requires moderate to heavy physical work, as studies show [1]. The reasons for this are the high sensorimotor skills and the high versatility of people in agriculture. As a result of high load weights, highly repetitive activities and ergonomically unfavourable postures, the musculoskeletal system of farmers is generally subjected to much stress. This may have a detrimental effect on farmers' health and lead to temporary or permanent incapacity for work [2].

Survey of the workload allows an insight into the difficulty of performing specific work processes. Each person performs tasks at different speeds, despite the same working conditions. This is due to the different productivity of people. The differentiation between individuals in the working world is not as significant as in the world of sport; however, a ratio of 1:1.5 to 1:2 can occur [3]. Other differences arise due to the gender-specific height and weight of farmers.

For the evaluation of the workload, the heart rate measurement can be used. An increased heart rate relates to an increased oxygen demand by the muscles, and increased circulation. The heart rate is influenced by emotional and mental stress, and working conditions. It records the total stress of the work and is determined by the R-wave of the electrocardiogram (ECG) [4].

The mental workload describes external factors influencing people mentally, such as work tasks and the related requirements, the physical environment, and social and organisational factors. These stresses affect the person in the form of mental stress. The stress is influenced by the individual characteristics and has the consequence that the same mental stress can have different effects. As a result, desirable effects can occur, affecting the working process positively. Adverse effects have a direct impact on the performance of a person, which leads to fatigue-related conditions, such as monotony, reduced vigilance and mental saturation [5].

The physical and mental workload usually occur simultaneously, but can theoretically be divided into sub-loads. The physical workload relates to the stress on the cardiovascular system, including the lungs and breathing, the muscular systems with tendons and ligaments, the skeletal system, including the spinal column, and the sense organs with nerves and glands. By means of the mental workload, the mental-informational and social-emotional stress can be quantified [6]. Commercial semi-automatic blood pressure devices are available from different manufacturers to record the heart rate and thus quantify the load.

The aim of this case study is to determine the physical and mental stress in the daily routine work in the Hühnermobil 225 during the autumn and winter periods.

MATERIAL UND METHOD

The data collection took place on a farm in Germany where organic eggs are produced with the Hühnermobil 225, which was designed for 225 laying hens and had an area of 14m². The pen consisted of a lower level, which served as the scratching area, and the upper warm region, where the feeding, watering, perches and nesting boxes were installed.

The daily work during the autumn and winter months was performed by 2 male and 2 female subjects aged between 16–31 years. The examined daily routines were feeding, monitoring, collecting and pre-sorting eggs. These activities, due to the frequent performance, enabled the comprehensive gender-specific data collection for men and women.

The heart rate measurement makes it possible to determine a measure of the total load of a person. In this static and dynamic work, mental and emotional stress and environmental factors are taken into account [7]. For recording the heart rate, the ECG and activity sensor of Movisens® was used. This is a psychophysiological ambulatory measurement system which is attached to the body with a chest strap. The dimensions of the device are 62.3 mm × 38.6 mm × 10.5 mm and it has a weight of 23.2 g. The sensor-amplifier ECG records the raw data of the ECG signal, the 3D acceleration sensor the movements, and the barometric altitude sensor records the air pressure and the temperature for up to several days.

Fluctuations in heart rhythm were represented by the heart rate variability. This provides information about the stress level of a person. Heart rate variability is referred to as a sensitive and specific indicator which can indicate acceptance of mental strain, decrease in fatigue and increase in relaxation and recreation [8]. The Baevsky Stress Index originates from Russian space medicine and describes the stress state of a person. The human body reacts to different influences by variations in the cardiovascular system; the hormone regulation, energy and metabolic mechanisms are also affected. The stress index shows the rhythm stabilisations and disorder reductions in the cardio-interval length, which are calculated from the histogram of the heart rhythm distribution curve [9].

Figure 2. ECG and activity sensor of Movisens® (photograph: Mayrhofer, 2015)

For analytical data analysis, the statistical program SAS 9.4® was used. As statistical test methods, the Generalized Linear Model (GLM) and the Logistic Regression (LR) were applied.

RESULTS AND DISCUSSION

The mean heart rate in the Hühnermobil 225 was 122 bpm, and clearly exceeded the endurance limit of 110 bpm according to Hartmann et al. 2013 [10].

Table 1. Average heart rate of daily routine work by gender (2015)

No. of persons and gender	Hühnermobil 225
	Average heart rate bpm ± SD
Male (n=4)	103 ± 35.3
Female (n=4)	137 ± 40.7

Divided by gender, the male subjects were below 103 bpm and the female subjects with 137 bpm above the endurance limit. The gender and the number of measurement runs were also significantly related to the heart rate of the daily routine. There were significant interdependencies between gender (0.0001 <0.05 h.s.), the number of measurement runs (0.0001 <0.05 h.s.), and between the subjects (0.0001 <0.05 h.s.) and within the genders (0.0001 <0.05 h.s., R = 0.99).

The female subjects had a 7.83-fold lower chance than the male subjects to exceed the heart rate limit of the endurance limit. The subjects with a lower level of fitness had a 23.1-fold higher chance to operate on the heart rate limit of the endurance limit than the subjects with better fitness.

Mayrhofer et al. (2015) [11] examined in their study the entire milking process and classified it as hard work for men and women, caused by an average heart rate of 106 bpm. Pebrian et al. (2014) [12] determined specific work processes in the agricultural sector as heavy work due to an average heart rate of the workers of 133 bpm.

The Baevsky Stress Index was determined for all activities using the Movisens® measuring device. The metrological recording of data was very patchy; consequently, evaluation of the data was performed by the subjects. Because of the low volume of data, averages by gender or activities could not be determined.

Table 2. Average Baevsky Stress Index in c. u. according to activities and subjects

Activities	Hühnermobil 225			
	P1 / m	P2 / m	P3 / f	P4 / f
Feeding (n=2)	312*	-	-	-
Monitoring (n=2)	51.1	-	-	-
Collecting eggs (n=2)	-	-	-	190*
Pre-sorting eggs (n=2)	54.8	-	-	164*

– = no measurement results, normal range: 50–150 c. u.
*elevated: 151–500 c. u.
**extremely elevated: > 500 c. u.
m – male; f – female)

For subjects 2 and 3 in the Hühnermobil 225 no data were documented. This high measurement error rate was repeated for the activities of feeding and monitoring for subject 4 and collecting eggs for subject 1. The recording of data by the device was insufficient; data quality was not sufficient for the algorithmic calculation. The normal stress index ranged from 50–150 c.u. The increased values indicate a limited adaptability of the person. Very high values from 500 c.u. showed exposure to stressors [9]. What kind of stress had occurred in this situation could not be determined. The huge data gaps were caused by a faulty attachment of the belt, high sweat production, or too much upper body movement. After measuring interruptions, the equipment needed around 15 minutes for the calibration in order to continue with the measurement. This does not have a strong effect for measurement periods of 12–24 hours; however, for measurements during short successive activities, this time is too long.

Hart (2014) [13] determined the stress index in the milking process and found a high measurement error rate with the same instrument. Berceli (2009) [14] found similar errors in the measurement of psychological stress with another measuring instrument, which impacted the quality of data.

CONCLUSIONS

Evaluation of the physical stress by activity was possible. For comparison, no other data from the field of laying hens has been available so far. Analysis of data on the entire working area of the management of mobile henhouses is useful as a basis for a detailed study of working conditions in the second step.

Recording of the data sets by gender offered the advantage of a separate assessment of the heart rate, and also revealed gender-specific differences in physical stress. It would be more useful to carry out an evaluation of a stable model using more subjects and the entire work area (routine and special tasks) in order to obtain a sufficient amount of data. The next step should be a comparison of different posture systems.

The wearing of the ECG activity sensor of Movisens® was not seen as a problem by the subjects. The application initially required a short setting and activation of the device via a laptop. Data storage and analysis with the accompanying software was easily performed. This measuring instrument was developed for the rehabilitation sector, and the presented study examined whether it could be used to monitor work processes in agriculture. The advantage of the device is that several parameters are measured and recorded during a working process.

The Baevsky Stress Index was used to determine the mental stress. This showed considerable measurement errors due to the poor sitting of the belt, high welding production, or too much movement of the upper body. After measurement interruptions, the device took about 15 minutes to calibrate to continue the measurement. Although this has little influence during measuring periods over 12 or 24 hours, this time is too long for measurements after short successive activities.

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