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Occupational illnesses related to physical strains in apple harvesting*

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Abstract

Introduction. Special strains are an occupational hazard often due to physical loads and inadequately designed work equipment.
Objective. The aim of this pilot study was to determine occupational illnesses related to physical strains through an experimental design that assesses the associated working postures and oxygen uptake in apple harvesting.Three methods were applied to define the physical stress provoked by apple farming tasks.
Material and methods. The experiments considered 5 labourers – 3 women and 2 men. The physical fatigue was assessed through oxygen consumption and heartbeat frequency according to UNI EN ISO 8996 standards. Measurements were conducted using a portable metabolimeter(COSMED). Working postures were determined according to Ovako Working Posture Analysis System(OWAS). An interview was conducted to record the labourers' subjective estimate of the stress.
Results. The interview results demonstrated neck and dorsal pains and fatigue causes for each operator. The $\dot{V}O_2$ was equal to 82.33±27.40 lO_2/h for women and 67.00±27.60 lO_2/h for men, meaning that it was tiring for some men but for all women. The heart rates were of 115±6.00bpm for women and 113±5.65bpm for men. The $\dot{V}CO_2$ was of 63.81±21.45 lCO_2/h for women and 45.10±25.53 lCO_2/h for men, while energetic equivalent and body surface area were similar for both genders, about 5.60W×h/l O_2 and 1,80m^2 on average. Women's metabolic rate had a very high value – over 290W×m^{-2}, although for the men it was between 200–260W×m^{-2}. According to OWAS, low apple picking was ranked in class 2, high apple picking in class 1, and apple transportation belonged to class 3.
Conclusion. Related to VO_2 and VCO_2 consumption and the identified negative body postures, it is necessary to improve working conditions.

Key words

physical stress; oxygen consumption; heart rate; metabolic rate; postures; occupational illness

* Authors have contributed equally to the present work

INTRODUCTION

Special strains in occupational hazards are often due to physical loads in the workplace. Excessive strains increase occupational illnesses and accidents and decrease work productivity. Apples are the predominant fruit culture with a cultivation area of 6,450 hectares mainly situated in Lower Austria, Upper Austria and Styria. The problems due to physical strains in apple farming that occur, especially in women, are accentuated because of age and chronic diseases[1]; therefore, structural developments in apple production will certainly bring profound changes in terms of working conditions and health status. The changing occupational risk factors come down from farm size increase and specialization [2]. Health and safety hazards in apple harvesting have not been studied in the required depth. Apple dessert harvesting, which is carried out manually, is labour intensive and requires up to 215 hours per hectare, and the picking time amounts to up to 70% of the whole activity time requirements, including transportation [3]. During apple picking, the workers cyclically perform many repetitive activities. Cyclic tasks are usually performed with muscles of the hands, arms, and shoulders, assisted by the eyes that require head and neck movements. A common repetitive activity will usually demand low energy consumption, but if it is short in duration and cyclic in performance, the recovery phases of the musculoskeletal organs are limited; therefore, this activity becomes strenuous [4]. In fact, apple picking and transportation require high energy expenditure and heavy spinal loading. In addition, repetitive arm movements contribute to the development of repetitive movement disorders [5]. These physical factors, i.e., repetition of posture and movements, n, are most often associated with chronic neck and shoulders pains which imply the influence of fatigue [6]. Persons with chronic back and neck pains have demonstrated decreased muscle strength [7, 8] and fatigue growth of the injured muscles. These methods used may be grouped into questionnaire and interview methods for charting the physical sensations arising in a person carrying out a certain labour, physiological methods for measuring the organic changes occurring when performing the work, as well as methods based on observation. In the case of studies dealing with the stress imposed by agricultural work, the

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energetic load imposed by the labour has been the most common object [9]. This has been carried out mainly by measuring oxygen uptake and energy costs. In the case of heavy physical work, energy consumption is commonly used as the basis for classifying works in terms of their stressfulness [10]. Energy consumption is generally determined on the basis of oxygen consumption or heartbeat frequency during the work.

Despite the availability of numerous methods based on work postures observations, an international classification for stress based on energy consumption does not exist. In addition to work postures, internationally approved classifications are also as yet unavailable for static stress and force use. These, however, can be used in making subjective estimates of the stress level and to compare work, stages of work and work methods [9]. Portable metabolic measurement systems have been used to quantify the oxygen uptake and energy cost of a wide range of activities, such as shovelling snow in healthy individuals [11]. The main objective of the presented case study was to evaluate and identify physiological fatigue and physical strains provoked by manual apple harvesting tasks, and subsequently, construct a predictive model indicating occupational illness causes and preventive measures to be taken, through an experimental design based on different postures and oxygen uptake levels.

MATERIALS AND METHOD

A typical Austrian company with a low number of workers on average was selected for this study. Trials were undertaken in the summer 2011 at the Schottengut Company in Vienna. A group of 5 agricultural operators: 2 males and 3 females, aged between 20–40, were examined while carrying out their daily working duties, that is, apple picking and transporting during about 8–10 hours per day. There was a break every 4–5 hours. The anthropometrics data of the operators are shown in Table 1. The apples were gathered from the ground and picked from the trees using small stepladders to reach the highest parts. The workers used big hip-belt bags to collect the fruit that were subsequently deposed in containers removing the apples from the bottom of the bag. The filled container was loaded by an opening in the bottom, and then pulled by a tractor to transport the fruits.

Table 1. Anthropometric data per gender of examined labourers (mean ± SD)

	Males (n=2)	**Females** (n=3)
Height (cm)	182.5 ± 10.6	173.3 ± 5
Weight (kg)	75 ± 18.34	76.6 ± 15.56
Body Mass Index (kg/m²)	22.30 ± 2.9	26.78 ± 4.44

First, a survey was conducted using a questionnaire contained questions about the labourers' characteristics and working conditions. A subsequent survey concerned the detection of musculoskeletal disorders in 9 different body areas during the analysis, as performed by Calisto [12]. Field analysis was conducted for each operator during approximately 50 minutes. Measurements were carried out using the portable metabolimeter K4b2 (COSMED). Analysis was undertaken applying the methods set by the European Regulations Regarding Thermal Environments – Determination of Metabolism Rate (UNI EN ISO 8996) [20] which states that: 'This international standard specifies different methods for the determination of metabolic rate in the context of ergonomics of the climatic working environment'. Estimations and data reported in this international standard concerned an 'average' individual, that is, a 30-year-old man weighing 70kg and 1.75m tall (body surface area 1.8m^2), or a 30-year-old woman, weighing 60kg and 1.70m tall (body surface area 1.6m^2). The Regulation outlines 4 levels for the determination of the metabolic rate. The fourth level that includes three methods was considered for this experiment since it gives the most accurate values which are precise to approximately +/-5%. The 4C method, which is a direct calorimetry method, was applied for energetic metabolic rate analysis and for estimating the strain and physical force of apple harvesters. Apple harvesting requires an elevated manpower (loading, unloading and transportation of full and empty containers) with notable energy expenditure. Through the monitoring of various respiratory parameters, the general sub-maximal force generated by this activity was analyzed, providing an overview of workers' health. Thus, the instrument analyzed the volume of O_2 consumed per minute($\dot{V}O_2$), volume of CO_2 produced per minute($\dot{V}CO_2$), heart rate(HR), maximum heart rate (HR_{max}), the kilocalories spent in one hour and the energy expenditure during work activities. The evaluation of stress and physical fatigue of each operator was achieved calculating the energy metabolism determined by the following equations:

$$RQ = \frac{\dot{V}_{CO_2}}{\dot{V}_{O_2}} \quad EE = (0.23RQ + 0.77RQ)5.88 \quad M = EE \times \dot{V}O_2 \times \frac{1}{A_{Du}}$$

RQ is the respiratory exchange ratio; $\dot{V}O_2$ – oxygen consumption rate(l O_2/h); $\dot{V}CO_2$ – carbon dioxide production rate (l CO_2/h); EE – energetic equivalent(W×h /l O_2); M – metabolic rate(W×m^{-2}); A_{DU} – body surface area(m^2), given by the Du Bois formula:

$$A_{Du} = 0.202 \times W_b^{0.425} \times H_b^{0.725}$$

where W_b is the body weight (kg) and H_b the body height (m).

The OWAS method evaluates the possible and various postures that the workers assume and concentrates on the weight intensity on the back, legs and arms. Each configuration was classified by a code for the four lesion and/or muscle skeletal risk classes with a four digit numerical value:

Class1 postures do not cause any kind of problems on musculoskeletal system; Class2 covers potentially harmful postures for which measures are recommended to implement necessary improvements;

Class3 identifies postures that cause harmful effects or situations to intervene as soon as possible;

Class4 is very harmful and requires safety measures to change the operation modes, the used equipments and workers' tasks.

Taking into account that the static muscles use depends on the size and quantity of muscles mass affected by the frequency and duration of the contractions, as well as on any applied force that can adversely affect the functioning of the respiratory and circulatory systems. The descriptive and analytical analyses were conducted using SAS 9.2. The generalized linear model (GLM) was used in order to determine the effect of gender, weight, height and $\dot{V}CO_2$ on $\dot{V}O_2$ behaviour. Residuals were normality distributed. General linear modelling was used because issues of residual, and model fit are as significant as they are with basic linear modelling, while conventional routine benchmarks are more complex internally. It is a single methodology for producing model parameters estimates [15].

RESULTS

The interview demonstrated that, depending on their personal characteristics, the operators felt great stress while harvesting apples. Labourers' features represented a wide morphology range: in age from 19–48 years, body weight 62–93kg, body height 1.68–1.90m, percentage body fat – 25.44±4.63 for women and 22.31±2.91 for men. During the tests undertaken in the field, the average volume of the consumed oxygen $\dot{V}O_2$ by the workers was analyzed. Applying the integral method (Level 4 – for experts) means that oxygen consumption level above 60 lO_2/h is considered heavy labour and tiring for the body [14]. In fact, this was 82.33±27.40 lO_2/h for women and 67.00±27.60 lO_2/h for men, meaning that whereas it was tiring for some men, it was tiring for all women due to their lower muscle mass. The woman is able to reach only 60% of the strength of a man, as reported Rohmert[16]. These results show that the mean of the oxygen uptake and metabolic rate for the women was about 15% higher than for the men. The general recommendation is an average value below 60 lO_2/h for subjects performing whole body physical work; this is 60% – 70% of an average $\dot{V}O_{2max}$ and should be performed continuously throughout the working day. Ahonen et al.[2] found that in milk production processes, oxygen consumption ($\dot{V}O_2$) is almost moderate for men (1.92±0.6 l/h/kg) and below the average for women (1.56±0.18 l/h/kg) and exceeded the expected value by 50%. Labour would have to be of a slow velocity when requiring such intense working periods so that muscle metabolism can eliminate the lactic acid. In addition, the volume of O_2 to compensate for the deficit is 4 l for light activity and up to 20 l for heavy activity[16]. Based on GLM analysis, a mixed model was used to identify the parameters influencing $\dot{V}O_2$ consumption (Tab. 2). The obtained results showed that young women workers (under 30 years old) used 12% less volume of oxygen than those aged over 30, who produced 13% less of their metabolic rate and also had a lower heart rate. The adult woman worker's heart rate value was over the threshold of linearity between heart rate and metabolic rate (121bpm). Table 3 shows significant influencing parameters on $\dot{V}O_2$ consumption for women workers. The measured HR was 115±6.00bpm for women and 113±5.65bpm for men; however, HR_{max} was 185.5±15.13 and 194.00±2.80bpm, respectively. Heart rate had a minimum difference of 2% between women and men, and was under 120bpm for both of them. However, it is known that under field conditions, the measured activity is not exactly the same from one experiment to another, a variation of up to 20% can be expected [17]. Calisto [15] applied heart rate measurements as one of the methods of studying working processes workload in apple and cherry orchards. He pointed out an average heart rate of 53.0±2.7bpm for all working tasks of apple production, although the results of harvesting tasks indicated higher values of about 100bpm. It was noted that these values were very similar to those measured in carried out trials. Prolonged high heart bpm could cause occupational diseases, and a higher energy demand than that given in the above-cited standard. Therefore, a dynamic activity generates excessive stress on the cardiovascular system that is not acceptable for a steady state [18]. $\dot{V}CO_2$ values were, respectively, 63.81±21.45 and 45.10±25.53 lO_2/h for women and men, and the EE was 5.66±0.030W×h/l O_2 for women and 5.60 ± 0.070W×h/l O_2 for men, corresponding to that established as the European norm [14]. A_{DU} values of 1.88±0.18m^2 for women and 1.80±0.28m^2 for men were considered normal because they match the international 'average' standard.

Table 2. GLM analysis of VO_2 consumption

Parameters	Pr[1]> F
Gender	< 0.001***
Age	< 0.01**
Weight (kg)	< 0.01**
VCO_2	< 0.001***

*** high significant
** medium significant
*significant
[1] Probability

Table 3. GLM analysis of $\dot{V}O_2$ consumption of women workers (n=3)

Parameters	Pr> F
Age	< 0.001***
Weight (kg)	<0.001***
VCO_2	<0.001***

*** high significant

The identified M values during the trials corresponded to 363.07±91.61 and 211.28±48.08W×m^{-2}, respectively, for women and men. According to metabolic rate classification given by the UNI EN ISO 8996 European standard, women's metabolic rate with a value over 290W×m^{-2} was very high, meaning that apple picking tasks were energy intensive. Men's metabolic rate was lower, but still high with 200 to 260W×m^{-2}. The energy produced by the women's group was 180±69.5Kcal/h and 4326Kcal/day; for the men's group it was of 217.25±83Kcal/h and 5214Kcal/day, demonstrating that the workers used a high amount of energy. Physical exhaustion was felt by apples harvesters who worked more than 8–10 hours per day. A person weighing 70kg has an average energy requirement of 7,100KJ or 1,689Kcal per day [16]. The achieved trials demonstrated, however, that apple picking demanded a higher energy in comparison with a moderate activity; indeed, it was 30% more for men and 20% more for women. According to Rodahl [10], the average oxygen uptake is 30%–50% less for a moderate activity than a maximal performance level such as apple picking. Jenik [19] found that the total energy consumed by apple pickers after a complete working day (8–10 h) was 4,300–4,800kcal/day. According to the OWAS, low apple picking was classified in class 2, because the operators backs' were bent, both arms were above the shoulders and they were kneeling on one or both knees. High apple picking belonged to class 1 since the back was straight, both arms were above the shoulders, and the operators were standing with their legs extended. Apple

Figure 1. Workers' positions during apple picking

Figure 2. Rotation of the back

Figure 3. Back bent

transportation appertained to class 3. It is necessary to take immediate preventative measures for classes 2 and 3, because of the considerable repetitive movements of the back, which moved down and up when picking low apples and carrying baskets weighing 15kg. For high apple picking, there was a total elongation of the body and a rotation of the pelvis to reach the apples. Farm managers are obliged to inform operators about the correct work positions.

Back movement at the tree was determined as class 1 because the back was straight, both arms were above the shoulders and legs were also straight. The unloading of apple baskets appertained also to class1 because the operators did not control the weight of the apples. Similar posture results related to the total harvesting time were mentioned by Richardson et al. [19]. Trunk movements during apple picking required about 34.9% of the whole operation time; this position was the worst for the body and required measures of class 3–4. Over 59.3% of the arms and shoulders movement time fitted into in class 2, and 24.5% of the legs movement time corresponded to class1. Overall, the workers who performed apple picking tasks suffered under repetitive movement high energy expenditure, a high heart rate and oxygen uptake, and negative postures. Many of the detrimental postures occurred while the apple bags were full or partially full; these situations increase the likelihood of muscles and joints strains and therefore require immediate optimization measures. According to Richardson et al. [19], it is possible to improve apple picking postures by improving devices design, for example, by removing the baskets and using portable containers or modified shoulder straps. Modified shoulder straps was a design intervention that added a wider padded section to the strap where it lies on the shoulder, and incorporated an elasticized suspension into the strap in two places to minimize the impact of sudden downward forces. Another modification would be a new closing hip belt and a metal hook. This intervention redistributes weight from the upper back, neck and shoulders to the hips.

CONCLUSIONS

Manual harvesting workers usually perform activities that are physically highly demanding. In order to characterize and identify the physical workers' sensations during apple harvesting, a quantitative investigation was conducted revealing a great physical stress. Therefore, it is necessary to consider workers' statements as well as indicative parameters measurements with the view to improve their working conditions. Metabolimeter measurements were performed to assess the physiological demand in apple picking. The critical situation during harvesting are depicted by the levels of the relevant parameters $\dot{V}O_2$, HR, M and EE. The registered $\dot{V}O_2$ average values were above the critical value of 60 lO_2/h that should not be exceeded by healthy workers during work. This corresponded to up to 70% of the $\dot{V}O_{2max}$ average performed continuously throughout the working day. The relatively high oxygen consumption was associated with the high weight of the apples bags. Additionally, apple picking can be considered as a dynamic labour that creates excessive stress and strains on the cardiovascular system that are not acceptable for the physiological structure; this because a high number of heartbeats per minute over a long period cause occupational diseases. Moreover, other factors, such as heat stress and an incomplete recovery during allowed rests, contribute to an elevated heart rate. At the same time, the obtained data revealed a higher energy demand than that given in the above-cited standard. In heavy and dynamic work, it is important to give a greater focus on metabolic energy production than on the muscular system. Determination of energy requirements is necessary for judging the use of energy transformation processes in respect of the viability of work, the working hours and the breaks. Results obtained by the OWAS method showed that postures were harmful during low apple picking, transportation and unloading of baskets. Overall, the excess of these related parameters compared to limits defined sub- maximal work situations.

One solution to reduce oxygen consumption and improve heart rate and postures could be the improvement of harvesting equipment, as well as better manual handling conditions supply, such as the hip belt intervention that aims to displace some of the load of the apple bags. Indeed, the hip belt bag redesign, supported by other studies, would be an effective improvement, after which a large-scale testing on the impact of such intervention on back, neck and shoulders pains and strains should be undertaken. A more fully developed orientation and training for bag users is recommended, to assure that a clear understanding of weight transfer mechanism is assimilated, and that bag adjustments are not time-consuming.

Further improvements could be the mechanization of apple harvesting and transportation, because such physically demanding work leads not only to physical fatigue, but it also engenders a productivity loss. From the obtained results, it emerges that there is a need for a systematic way of workers' activities organization that allows them sufficient breaks and does not delay the schedule. The presented pilot study shows that a rest allowance corresponding to about 10% of the working time and a lower work pace should be offered during apple picking, its determination can be improved by further researches, based on the results indicated above. Additionally, work rotation creates positive effects on workers' stress, because it significantly decreases both the perceived and the energetic load. In conclusion, in order to improve operators' working conditions during apple harvest and to reduce health risks, it is necessary to periodically modify their duties, improve harvesting equipments and arrange more frequent breaks to optimize the oxygen uptake and the related parameters as well as posture.

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