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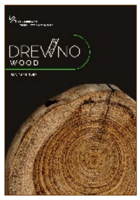

Efficiency and Ability of Employees to Work in Relation to Timber Quality and Structural Ageing

Krzysztof Leszczyński*

Faculty of Forestry, University of Agriculture in Krakow, Poland

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Small and medium-sized enterprises play a crucial role in job creation in the wood industry. The process of employee ageing and avoidance of heavy physical effort affect the labour market contribution. The need to increase work efficiency is certainly reflected in the pressures on employees. Workplace health investigations with the Work Ability Index (WAI) is a one of several tools that take into account job requirements, the employee health status and their resources. In the conducted study, an attempt was made to assess the workability of logging workers in the private sector of small and medium-sized enterprises. Excellent work readiness was found only among harvester and forwarder operators aged 20-30. Different dynamics of WAI decline as a function of age were also observed. In general, for the study group, the WAI fluctuated at a moderate level depending on the technical equipment, age of the employees, BMI, log dimensions and quality (pulp, industry or large saw log wood) or machine productivity. The worst situation was observed during silvicultural treatments of deciduous (beech) stands using the cut-to-length (short saw log wood harvesting) method. Ageing, being overweight, deteriorating health and the mainly physical nature of work are risk factors for low (mediocre) work capacity. It can partially be modelled by increasing employee engagement through an appropriate incentive system. We often observed differences between the work demands determined by the employer's expectations and the social, physical, and health limitations of employees, which led them to seek easier jobs.

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Introduction

The wood-based industry is an important part of the European Union (EU) manufacturing sector that can help to achieve higher gross domestic products [Sertić et al. 2018]. In the past two decades roundwood production in the EU rose by 26%. Around one in five manufacturing enterprises were active in wood-based industries across the EU in 2020 [Eurostat 2022]. At the same time, employment has fallen by more than 10%, particularly in the private service logging sector. The forestry-based sector is subject to constant fluctuations and adjustments in line with the general economic situation and play a crucial role in the bioeconomy [Mihelic et al. 2018; Adamowicz and Górna 2020; Dyjakon et al. 2020; Jonsson et al. 2021]. The structure of the EU labour market has changed significantly over the past period. Relevant are the findings that there is a growing share of employed people aged 55-64 and a decreasing share of employed people aged 15-24 between 2009 and 2021 [Eurostat 2023].

* Corresponding author: krzysztof.leszczynski@urk.edu.pl

The labour market is constantly fluctuating, which we also observe in the wood industry. After the economic boom, a slowdown or even a decline in both Polish forestry and logging employment can be observed. In 2020, only 400 employment positions were created [GUS 2021a], which is slightly more than during the 2008-2009 crisis. At the same time, the employment structure in Poland shows an increment in the share of older people in the job market [GUS 2021b]. The need to raise labour efficiency is certainly reflected in the pressure on employees. Increased psychological pressure is also associated with increased musculoskeletal strain [Hagen et al. 1998]. Mansour [2016] demonstrated the impact of the indirect and intangible costs of employee dissatisfaction due to unpleasant or non-ergonomic working conditions on the productivity, profitability and quality of work.

Statistics show that 80% of accidents are caused by human error, mainly owing to tiredness. Brecher [2014] emphasises that work performance is influenced by both the work environment, employee behaviour and motivation, which is derived from the impact of workplace management. One of the theories used to diagnose the risk of ergonomic factors is the principle of flexibility (stress-strain) and feedback (receptor-effector) in work systems.

In response to the problems and challenges that have been clearly identified in industry, the Finnish Institute of Occupational Medicine in Helsinki proposed the Work Ability Index (WAI) survey as early as the 1990s [Tuomi et al. 1998]. These surveys were originally designed to assess groups of workers by an occupational health professional. More recently, their effectiveness has also been demonstrated when used by so-called non-occupational health professionals [Geissler et al. 2005].

Occupational health assessment using WAI tools takes into account the demands of the job, the worker's health status and resources. The developed model of work ability assumes an interaction between one's own abilities and the demands of the job. Ensuring a balance between the two is essential for maintaining good work ability [Malińska et al. 2019] and also indicates the degree of workload or overload.

Although statistics show that the frequency of accidents in forestry (5.95 per 1,000 workers) is twice as low as in mining, for example [GUS 2021b, 2021a], the frequency of fatal accidents, especially in private forestry enterprises is 38% higher at 0.18 deaths per 1,000 employees [Grzywiński et al. 2020]. The number of days of incapacity to work per injured person in forestry is 52.6, almost ¼ higher than the national average [GUS 2021a].

Therefore, the aim of this study was to determine the work capacity of people employed in private logging companies. Although the assessment is subjective in nature, based on the voluntary responses of respondents, according to Makowiec-Dąbrowska et al. [2008], it has more advantages than a health assessment. It seems important to identify the groups of workers with the lowest WAI scores and to try to identify key factors such as the technological system, economic process, age and physical fitness as expressed by BMI (body mass index), among others.

Methods

Surveys were generally carried out in the south-western part of the country, with volunteers from 36 types of workplaces (180 surveys). They were differentiated by the technological system, which was dominated by the cut-to-length (CTL) and long wood (LWS) systems, implemented in accordance with the current Forest Management Regulations [Appendix 1 to DGLP Order No. 66 2019]. The technical level included both hand-machine (harvesting with a chainsaw, skidding with a skidder or a universal tractor with specialised equipment: a rope winch, a trailer with a hydraulic crane) and machine logging (a harvester and a forwarder). Observations were made during harvesting operations of the so-called commercial timber harvest, early and late thinning (pulp or industry wood – small or medium-sized, 4-6-meter-long lumber) and final felling (saw log, medium or large dimensional lumber, 8-12 meters long). The analyses included observations of operations in coniferous stands (pine, less frequently fir and spruce) and broadleaved stands (mainly beech, less frequently oak). The respondents (men) were informed about the purpose of the study and their anonymity was guaranteed. The work ability survey was conducted using an abbreviated version of the WAI questionnaire questions [WAI-NETZWERK 2018], covering seven topics:

1. Current ability to work compared to best in life (0-10 points).
2. Ability to work related to physical and mental demands (2-10 points).
3. Number of current medical conditions diagnosed by a doctor (7-1 points).
4. Estimated impairment due to medical conditions (1-6 points).
5. Absence due to sickness in the last 12 months (1-5 points).
6. Own forecast of ability to work in the next two years (1-7 points).
7. Mental resources – pleasure, activity, optimism (1-4 points).

The obtained total score was assigned to the following categories of work ability:

– 44-49 points: excellent – maintenance of working capacity

- 37-43 points: good – proper ability to work
- 28-36 points: moderate – proper in working capacity
- 7-27 points: mediocre – restoration of working capacity.

The measurement of the working time structure for the technology variant was carried out according to IUFRO methodology [Ackerman et al. 2014]. It included observation of the whole working day together with measurement of the volume of timber harvested without bark. In this article, only the operational productivity values that accompanied the simultaneous work ability assessment (WAI) were used.

Statistical analyses focused on determining the measures of position. The trend of change was determined using exponentially smoothed curves. In order to reduce the dimensions and determine the degree of dependence (expressed in terms of the normalised value of the eigenvector) between the factors, principal components were searched for using the PCA (principal component analysis) module available in the Statistica 13.3 statistical package [TIBCO Software Inc. 2017].

Results

It was found that machine technology was dominated by workers in the younger age groups (up to 40 years), while hand-machine technology involved workers up to retirement age (60+) (Tables 1 and 2). The productivity of the hand-machine technology was 35% lower (7 m^3/h) than that of the machine technology. Overall, the WAI results can be considered satisfactory as the group of workers in manual machine technology had a moderate work capacity, while the group of workers in machine technology had a higher, good work capacity.

If we take BMI as an indicator of physical fitness, it is worth noting that the machinery group had the lowest BMI. In general, they were all overweight. However, BMI should be used with caution as it can be biased toward people with large amounts of muscle tissue.

Table 1. Positional statistics of analysed groups of workers in hand-machine technology

Age group	Operational efficiency, W02 $m^3 \cdot h^{-1}$	BMI	WAI, average	WAI, standard deviation
Petrol chainsaw operator, n=85				
20	6.10	23.96	43.7	8.80
30	12.84	23.99	35.5	5.10
40	2.86	26.48	28.3	6.60
50	3.74	25.46	36.9	5.78
60	9.00	32.18	21.0	0.00
Skidder or universal tractor operator with rope winch, n=30				
30	6.65	29.61	41.0	0.00
40	4.63	29.09	33.8	3.47
50	11.73	29.6	33.2	1.82
Universal tractor operator with forestry trailer, n=20				
40	8.00	30.67	37.2	2.95
50	5.22	29.06	31.0	2.10

Table 2. Positional statistics of analysed groups of workers in machine technology

Age group	Operational efficiency, W02 $m^3 \cdot h^{-1}$	BMI	WAI, average	WAI, standard deviation
Forwarder operator, n=20				
20	5.39	24.93	44.2	2.17
30	8.44	28.41	42.0	1.17
Harvester operator, n=25				
20	16.51	24.54	48.0	0.00
30	17.24	29.05	45.1	1.64
40	6.37	27.74	39.2	2.59

Weekly changes in the WAI score include variations within questions 1 and 2 of the survey. The presented results (Fig. 1) show consistent scores during final felling and late thinning operations. Greater variation was observed during early thinning operations, with the lowest scores recorded at the beginning and end of the week.

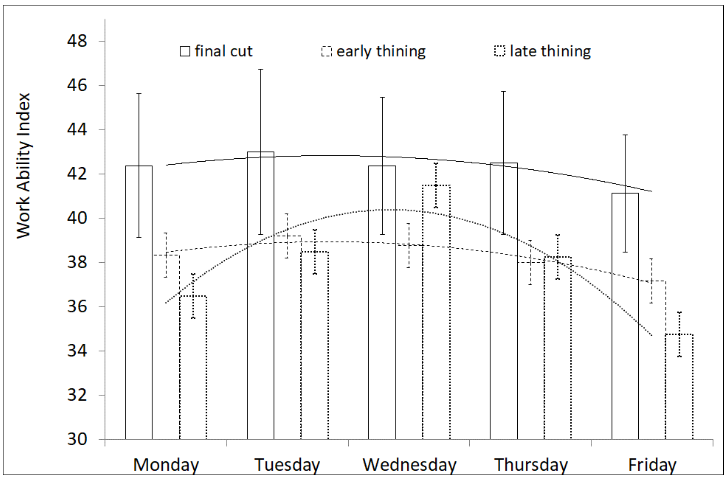

Fig. 1. Fluctuation in WAI scores over 5-day working week (overall trend, mean, standard deviation)

The cross-sections of changes in work ability (WAI) as a function of age show a general downward trend and little variation by the type of thinning treatment (Fig. 2a). As age rises, WAI decreases to a lower moderate or even poor (mediocre) level. Workers older than 50 years of age were characterised by a moderate work ability in beech stands and with the CTL method (Fig. 2c, d).

Excellent work ability was only observed for machine operators aged 20-30 (Fig. 2b) in harvesting (machine) technology. Extrapolation of the trend in WAI changes for mechanical harvesters predicts a sharp decline in “fitness” beyond the contractual age of 40. The dynamics of change in the WAI scores observed for manual harvesters is not as rapid.

There is a noticeable link here with declining health and reported medical conditions. Nearly 32% of the respondents reported the presence of diagnosed and undiagnosed conditions, including: accidental injuries (40%), cardiovascular disease (14%), respiratory disease (13%), digestive disease (13%) and other conditions (20%).

Younger people (< 25 years) employed as operators of large, powerful machinery (harvesters, forwarders) reported no complaints or illnesses. This group also emphasised that they took active precautions against occupational diseases.

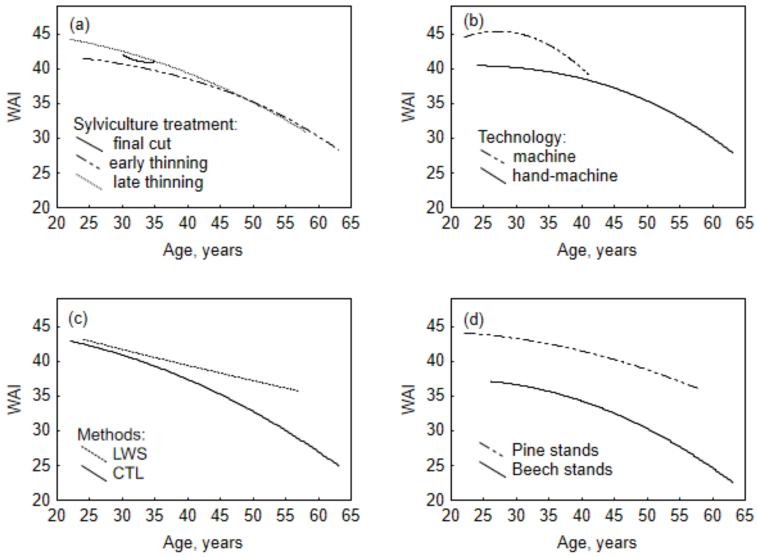

Fig. 2. Work readiness as a function of workers' age

Further analyses looked for the principal component within the identified five variables. Only two proved to be the most significant, explaining a total of 78% of the variability (Fig. 3). In addition, the third factor explains a further 13% of the variability, and the calculated eigenvalue of 0.66 (less than one) indicates its limited significance (Fig. 4a, b). The results indicate the interconnectedness of the variables, which in this case are the coordinate normalised values of the eigenvectors.

Comparing Fig. 3 and Fig. 4, it can be concluded that the WAI score is negatively correlated with BMI, an indicator of fitness and willingness to engage in physical activity. However, factor 1 is the most significant, explaining more than 51% of the variation. It indicates that the Work Ability Index and the age of the employee are the most strongly represented and negatively correlated. This means that as the age or work experience of the employee increases, the ability to work decreases. If the third factor is taken into account, it is clear that the observed operational efficiency is negatively correlated with BMI, i.e. the higher the BMI, the lower the work productivity.

The analysis of Fig. 3 and Fig. 4 also allows us to conclude that operational work efficiency (W02) has limited relevance for the observation of work ability (WAI). Productivity (W02) decreases with the age of the worker and shows little relationship with BMI and WAI.

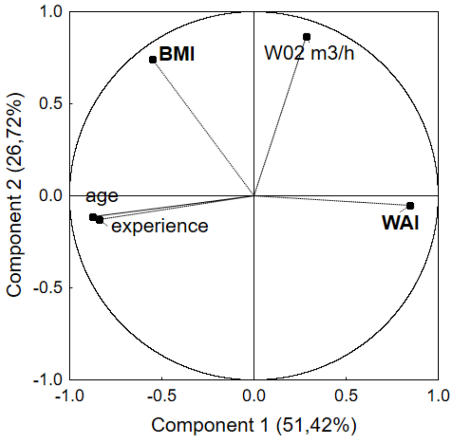

Fig. 3. Relationship of analysed characteristics to main two components

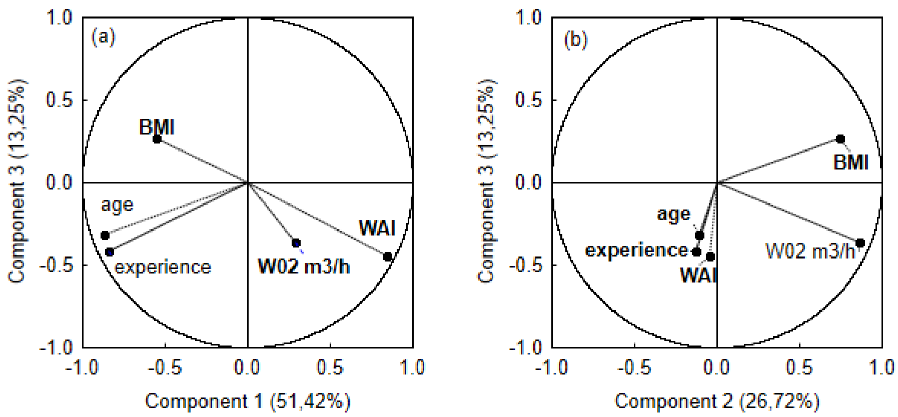

Fig. 4. Relationship of analysed characteristics to additional (third) components

Discussion

Work ability validation is becoming an increasingly important tool. Research on perceived work ability was the subject of an analysis by Bascour-Sandoval et al. [2020], who pointed to its consistency and relevance as a reliable tool for assessing work ability in the population. The intangible costs of stress and inadequate working conditions are often overlooked. Nonetheless, as Mansour [2016] notes, the disabilities resulting from working conditions have a dimension of hidden costs that are externalised through a reduction in the quality of production, the number of accidents or an increase in absenteeism.

In a cross-sectional study of forestry workers in Norway, Hagen et al. [1998] investigated the prevalence of neck, shoulder and lower back disorders and their relationship to work tasks and perceived psychosocial work stress. They found that musculoskeletal disorders were more common among manual workers than among administrative workers. For machine operators and manual workers, increasing levels of psychological demands were significantly associated with an increase in the prevalence of lumbar spine disorders. The prevalence of neck and shoulder disorders was significantly higher among machine operators and manual workers than among administrative workers. Both physical and psychosocial risk factors appeared to be related to the cause of the disorders.

Research by Makowiec-Dąbrowska et al. [2008], conducted among occupational groups of workers employed and working in Poland shows that the level of work ability in the study group was good, but lower than in similar occupational groups in other European countries. Job characteristics and individual characteristics of workers have a stronger influence than health factors. They also found that stressful work, low stress tolerance and personality traits were risk factors for low or moderate WAI scores. The study confirmed that in the male group, a balanced diet and physical activity were factors that reduced work-related risk. The authors also point out that the underestimation of Polish people as a whole is partly a consequence of a common tendency towards low self-esteem and complaining.

A review of the literature by van den Berg et al. [2008] suggests an association between high mental work demands and poor WAI as a result of a lack of autonomy. High physical demands such as increased muscle work, poor posture and poor ergonomic conditions were positively associated with a lower WAI. In addition, a national study [Makowiec-Dąbrowska et al. 2008] found that 60% of male respondents had a high tolerance for increased physical exertion.

Kymäläinen et al. [2021] stated that for forestry machine operators, breaks combined with inactivity or other physical activity should be considered as elements to maintain vitality and concentration at work.

A large population study conducted in Luxembourg [El Fassi et al. 2013] suggests that ageing, being overweight, deteriorating health and the predominantly physical nature of the work increase the risk of illness and are causes of low work capacity.

Croatians [Landekić et al. 2013] point to incomparably higher mental stress among machine operators in the private forestry sector compared to the public sector. They also note that responsive management, such as through continuing education, training and coaching, increases employee motivation and significantly reduces the effects of ageing. They also point out that neglect in this area has been the cause of the drastic decline in the working ability of operators employed in the private forestry sector.

Despite the inevitable changes related to the overall efficiency of workers and the stress caused by psychosocial factors, it is emphasised that the downward trend can be halted by an appropriate system of employee motivation. This also means that maintaining work efficiency is associated with a greater work demand from older workers.

Freudenberger [1974] referred to the state of mental and physical exhaustion caused by work life, the loss of motivation when activities do not produce the desired results, as job burnout. Looking at job burnout and employee engagement, it has been shown that they are related to job performance [Bakker et al. 2014]. However, burnout seems to be more related to health factors, while employee engagement is more related to motivation.

Work ability assessments are therefore widely used as part of an occupational health and safety management system [Landekić et al. 2013]. They allow one to demonstrate how well a worker is able to perform his or her daily work tasks and are used to assess work ability within a functioning occupational health system. The questionnaire-based tool is designed to support employees and allows the early identification of appropriate measures to maintain the work ability of individuals or groups of employees.

The study confirms the generally observed trends of a higher acceptance of physical workload and low tolerance to mental stress due to the complexity of work activities and temporal pressure occurring in high efficiency machine logging. Therefore, the results show the reasons for workplace changes among forest employees as an age-related process. It seems that the compensation model indicating the need for training, obtaining other qualifications, and improving qualifications enriches the motivation system, and thus reduces the negative aspects of the aging process, the excepted resignation from professional activity.

Häggström and Lindroos [2016] considered the reasons for the stagnant development of logging technology in Scandinavian forests. They emphasised that the system of mechanised operations should be considered in a human, technology, organisation and environment (HTO-E) system. For a CTL system to be effective, skills, technology and training alone are not enough. Solutions must be sought in education, training and automation. They identified cooperation between harvesters and transporters, inter- and intra-organisational cooperation and knowledge sharing as important areas for improvement and development. They also stressed that automation makes it difficult to predict outcomes. Nevertheless, the consequences of failure can be detrimental to productivity and safety in mechanised forestry. The ability to develop and implement systemic solutions provides a basis for understanding today's work and making informed predictions for the future.

Workplace health promotion is valuable in terms of reducing sickness absenteeism. Kuoppala et al. [2008] indicate that interventions involving lifestyle and ergonomics are effective and should address both the physical and psychosocial working environment.

Conclusions

The Work Ability Index takes into account the demands of the job, the worker's health and resources. The results reveal that there is little difference in the WAI scores for harvesters in final clearcutting (saw log logging) and thinning (pulp or industrial wood logging). There was a downward trend in the WAI scores as a function of age, which was moderate overall for the study group. Excellent work readiness was only found for harvester and forwarder operators aged 20-30. Unfortunately, by logging heavy and heavily branched wood short logs in beech stands or using the cut-to-length method (medium or large-sized short logs), workers over 50 years of age exhibited a mediocre work capacity. There is a correlation between declining health and reported health problems. Principal component analysis (PCA) shows a negative correlation between BMI and age with WAI volume. A decrease in operational work efficiency (W02) is weakly correlated with workers' ability (WAI) and fitness (BMI). Age, obesity, deteriorating health and the predominantly physical nature of the work raise the health risk and should be seen as causes of low work capacity, which can be modelled by increasing employee engagement through an appropriate incentive system.

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