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ERGONOMIC ASSESSMENT OF LOADING THE MUSCULOSKELETAL SYSTEM OF WORKERS IN THE GEOTEXTILE PRODUCTION PROCESS¹

Paweł Kielbasa*, Joanna Palmowska, Tomasz Szelaĝ

Institute of Machinery Management, Ergonomics and Production Processes
University of Agriculture in Krakow

*Contact details: ul. Balicka 116B, 30-149 Kraków, e-mail: pawel.kielbasa@ur.krakow.pl

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ABSTRACT

It is estimated that in the European countries approx. 27% of people works for more than half time of their work in a tiresome position resulting in muscle pains, which may disturb coordination of the posture, which increases the risk and possibility of error during operation of the machine. The tests concerned estimation of the risk of the musculoskeletal system disorders of workers who operate on particular work stations, which constitute a technological line for production of geotextile. Moreover, an attempt to improve organization of work was made in order to minimize the impact of the unfavourable postural system of a man on his/her health. Using the "OWAS" method (*Ovako Working Posture Analysis System*) the size and structure of loading of the workers' musculoskeletal system was determined. It was reported that on all work stations, which constituted the subject of the research, the 1st category of evaluation, where loading with the statical work was average but acceptable, prevailed.

Introduction

The assessment of the risk related to impairment of the musculoskeletal system, which results from performance of professional activities was the object of the research carried out by a number of authors and concerned in principle each production activity of a human. Roman-Liu (2008) based on the analysis of the exposure to musculoskeletal disorders in the EU countries, stated that occurrence of tiring and painful body positions mainly concerns persons within the age of 40-50 and focuses mainly on three sectors of economy i.e. agriculture and fishery and the construction industry. Other research prove that over 62% of employees is exposed for at least 25% of the working time to performance of repeatable motions of arms and hands (Parent-Thirion et al., 2007). It is relatively easy to estimate loading of the motor system through a visual observation of the body position at work and measurement of the time of the employee's stay in a particular position with the OWAS

¹ The paper was written as a part of the statutory research

method (*Ovako Working Posture Analysis System*). Suitable tables, which classify the body position of a man at work, were developed (Corlet et al., 1979). With the use of the OWAS method (Karhu et al., 1986; Kivi et al., 1991) carried out the quantity analysis of the standard positions, taken during work, with the use of the external forces values. Roman-Liu et al. (2010) carried out the research of the following work stations with the "OWAS" method: a renovator of ventilating trunks and a work station responsible for maintenance of a heating substation, Groborz et al. (2005) used, inter alia, the OWAS method for estimation of loading employees, working at the poultry farm, with work and the obtained results were similar to the results obtained with the HRR ratio method (the heart rate reserve ratio). The same method was used by Kai Way Li et al. (1999) and Tzu-Hsien Lee et al. (2013) for assessment of loading the musculoskeletal system during the construction works. Kielbasa et al. (2008) determined postural load of milkers working at the mechanical milking of cows. Undoubtedly, geometry of the working station, which many times forces position of a worker during manipulation activities, is significant. Muscular pains may cause that involuntary changes of the body position disturb coordination of a posture, which increases the risk and possibility of error during operation of a machine. It is significant in the process of the quality management (Korenko, 2014). This unsatisfactory state of affairs may be intensified by economic factors, which result in adapting non-production buildings for such purposes. Thus, carrying out the research with this regard and optimization of work stations on account of minimization of threats for the musculoskeletal system of a man seems to be justified.

Purpose, scope and methodology of research

The objective of the paper was to determine the size and structure of the static load of workers at the particular work stations during realization of the geotextile production process and its impact on the musculoskeletal system of the examined persons.

The object of the research was the system in the form of a man - a work station. In this case five working stations were analysed (operation of a carding machine, a textile machine line, a needling machine, a cutter, a packing machine). The scope of the research covered preparation of the time study of the working time for three workers operating on each of five investigated working stations, which constituted a technological line. Moreover, after a degree of loading the musculoskeletal system of the examined workers was determined, activities, which are particularly dangerous from the point of view of possible lesions, were selected and those, at which an improper postural system follows mainly from the workers' subjective habits, were indicated. A technological characteristic of the said working stations and machines, which comprise a technological line of geotextile production, was presented in the publication on the acoustic environment of the said production process – Kielbasa et al. (2013). The tests were carried out in PCPW Eko-Karpaty where the time study of a working day of employees on the work stations, which comprise the technological line of geotextile production, were carried out with the film method. A full cycle of work, performed by workers, who operate particular machines of a production line, was registered. Based on the post-frame analysis (each second of the film was analysed) activities were selected including variability of the taken bodily positions, pressed forces and time of their performance. A picture of a work day was carried out with the use of a digital camera Sony

DCR-PC1000E at the speed of 24 expositions per second. With the use of a computer program based on the algorithm of the OWAS method (*Ovako Working Posture Analysis System*) the quantity analysis of the standard positions taken during work, including external forces values, was carried out. The OWAS method enables classification of the body position and the external loading values. Digits, which describe component back, shoulders and legs positions, form the work position code. Based on the position code, a particular work position was qualified to one out of four categories of the assessment. Whereas, after including the accumulative time of maintaining this position during technological activities performed by a worker and frequency of changes, loading of the musculoskeletal system was qualified as: small, average or big (Kielbasa et al., 2008). Recommendations concerning revision of the actual state resulted from the degree of loading of the musculoskeletal system.

Analysis of the research results

A prevailing body position, taken by the tested workers, who operated the initial stage of geotextile production (fig. 1) i.e. a work station for operation of a carding machine (Kielbasa et al., 2013), acc. to the classification of the "OWAS" method, was characterized with the fact that a worker for 75.4% of the shift time had straight back at the relatively low coefficient of variability, which was approx. 5.5%.

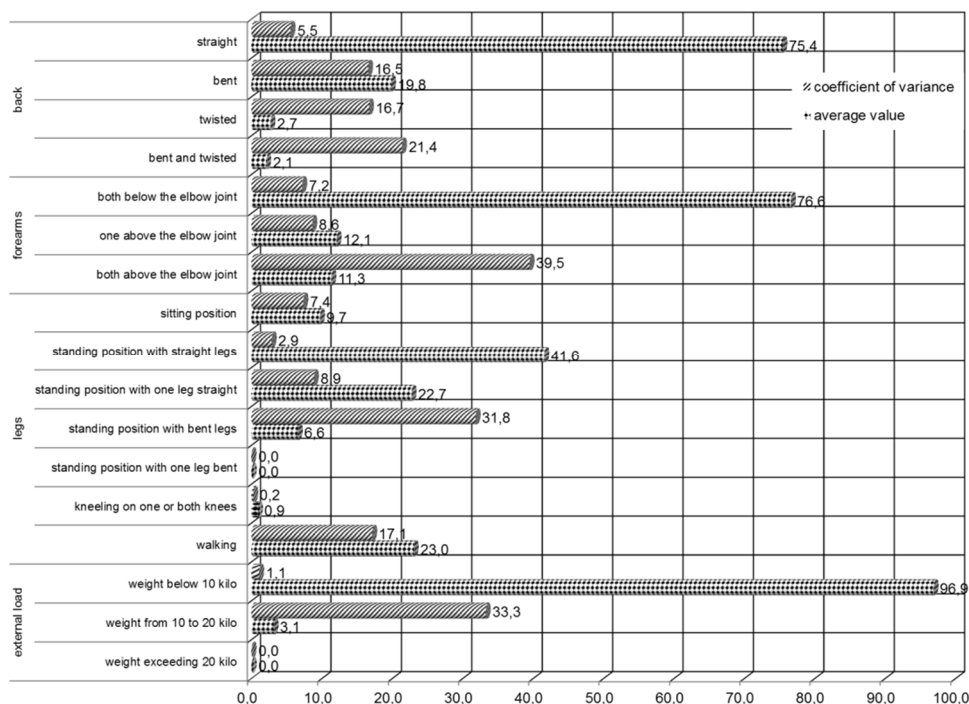


Figure 1. The time structure of maintaining a particular position during a work shift at the station operating a carding machine

Taking into consideration the most unfavourable back position for a man from the point of view of possible lesions, that is, a bent and twisted back, at the said work station such position was maintained only for 2.1% of the total working time. Attention should be paid to a high coefficient of variation, which exceeds 21%, which may prove a significant impact of the individual technique of performing activities by the investigated workers on the postural system. Analysing the position of forearms during operation of a carding machine, it was determined that a position, in which both arms are below the elbow joint constituted 76.6% of the total working time and was characterized with a low coefficient of variance, which was only 7%. In case of the position of legs of the investigated workers, a position in which both legs were straight (46.1% of the working time) was prevailing at the coefficient of variance of 2.9%. Weight of the lifted material in 96.6% did not exceed 10 kilo. Taking into consideration combination of the listed human body parts, described in the used method with four digits, it was stated that in the working time structure, an employee took a position described with the code "1121". Whereas, loading of the musculoskeletal system was classified to the 1st category of the assessment. In case of the 2nd category of assessing the load, the worker's position could be described the most frequently with the code "2121" (bent back, both forearms below the elbow joint, working in a standing position with straight legs). Moreover, at the analysed work station, 3 different codes of the body position, comprising the 3rd category of loading with the static work as well as 2 codes of the body positions comprising the 4th category of assessing the load were reported. However, their participation in the employee's working time structure was marginal. In the structure of operation of a carding machine, 7 groups of activities were selected, out of which the control of the machine, which constituted approx. 59% of the working time had the highest participation, including two categories of assessing the load, i.e.: The 1st category and the 2nd category constituting respectively 47.4% and 12.3% of the shift time of the listed categories. Activities related to the process of including a carding machine were the shortest, that is only approx. 3% of the employee's working time.

Generally, as much as 73.8% of the working time at the operation of a carding machine was classified to the 1st category of loading of the musculoskeletal system (fig. 2). In case of the 2nd category, its participation in the working time structure constituted 21.5% and the 3rd category only 4.5%. Whereas, the most unfavourable category, from the point of view of a worker, that is the 4th category constituted only 0.3% in the working time structure.

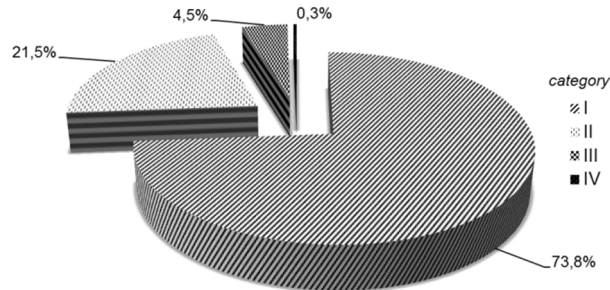


Figure 2. The structure of the category of loading at the station operating a carding machine

During the second stage of the technological process of geotextile production (operation of a technological line), a worker maintained a straight position of his back for 78.8% of the working time and the coefficient of variance was 39.9% (fig.3).

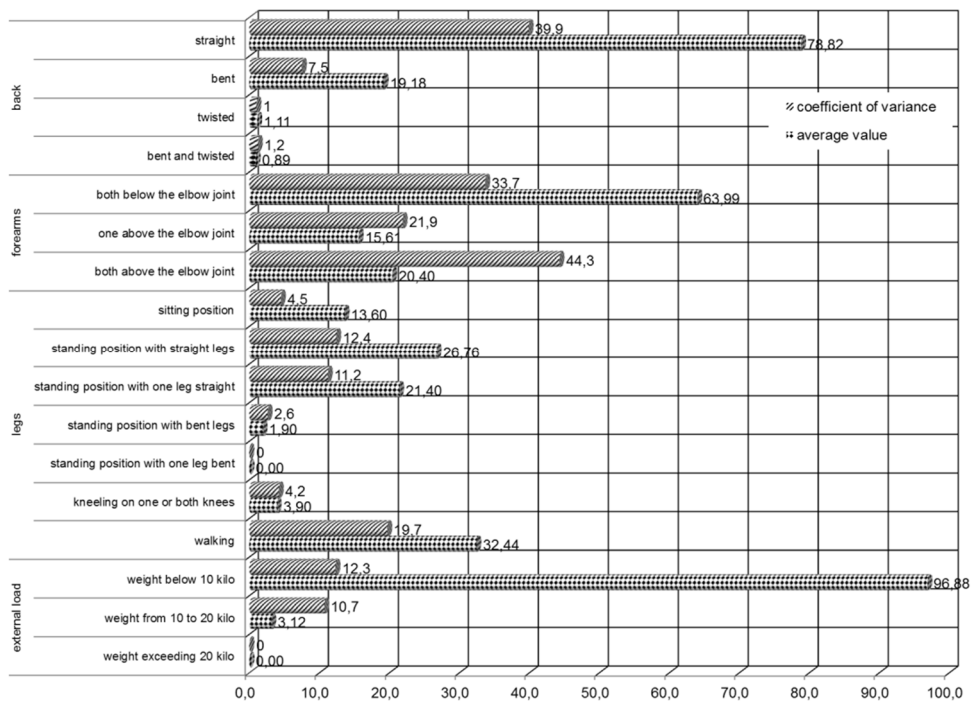


Figure 3. The time structure of maintaining a given position during a work shift at the station operating a textile machine line

When analysing the worker's forearms position, it was reported that over 63% of the working time both forearms were below and 20.4% were above the elbow joint. It should be emphasized that there was a considerable variability in the above mentioned value between the tested persons (the coefficient of variability was within 33.7-44.3%) which may prove considerable individualization of the manner of performing the activity.

Work consisting in operation of the technological line required from a worker constant walking for 32.4% of the working time, whereas the sitting position could be maintained only for 13.6% of the shift. A coefficient of variance, which is 19.7% in case of the "walking" activity, should be emphasized. It proves that in case of a relevant arrangement of work, time for this activity could be lowered. This statement does not refer to the kneeling position, which in the working time structure was 3.9% and was characterized with approx. 4% coefficient of variance. It was reported that in case of the 1st category of loading with the static work, the body position described with the code "1171" appeared. This code meant that a worker was walking with his back straight, he kept his forearms below the elbow joint and the weight of the carried material did not exceed 10 kilo. Whereas, among positions belonging to the 2nd category of the static load the position described with the code "2131" prevailed (it constituted 5.8% of the working time), which meant that the employee had his back bent, both forearms were below the elbow joint, he was working in the standing position with one leg straight and the weight of the handled material similarly to the previous case did not exceed 10 kilo. In the 3rd category of loading, the position, which was maintained for the longest time (1.4% during a shift) was defined with the "2141" code, which stands for the bent back, forearms below the elbow joint, a standing position with bent legs.

It was reported that the most time-consuming activities, performed by a worker who operated a textile machine line was control of the machine operation – 35.9% (fig.4) and batching of polyester fibres to the feeder – 28.9% of the working time. Carrying bales with non-woven fabric was the shortest activity – it took 1.8% of the working time.

During each of the performed activities at the analysed station, the 1st category of the static load prevailed – 79.71% of the working time. The activity consisting in cutting out the non-woven fabric samples was an exception, which was almost entirely classified as the 3rd category of assessing loading with the static work. Taking into consideration the time of maintaining one position, the static load was at the average level.

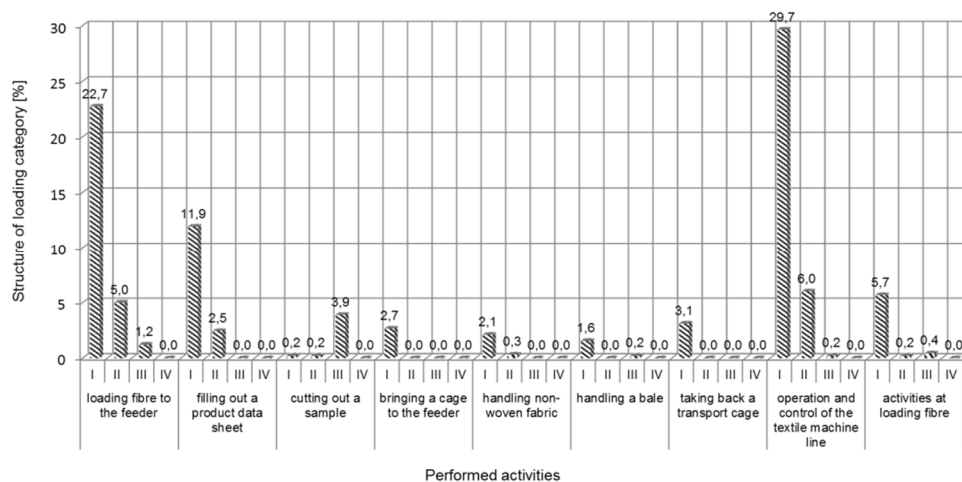


Figure 4. The structure of the loading categories during performance of activities at the station operating a textile machine line

During operation of the needling machine, which is the third stage of geotextile production, the most popular back position of workers, who carry out the technological process, is a straight back, which constitutes 66% of the shift (fig. 5).

It was stated that in the working time structure as much as 76.9% both forearms were below the elbow joint. The examined workers carried out their activities mainly (44.8% of the work shift time) in the standing position with straight legs. High variability in case of the back position, which was twisted, should be emphasized. It was 162% expressed with the coefficient of variance.

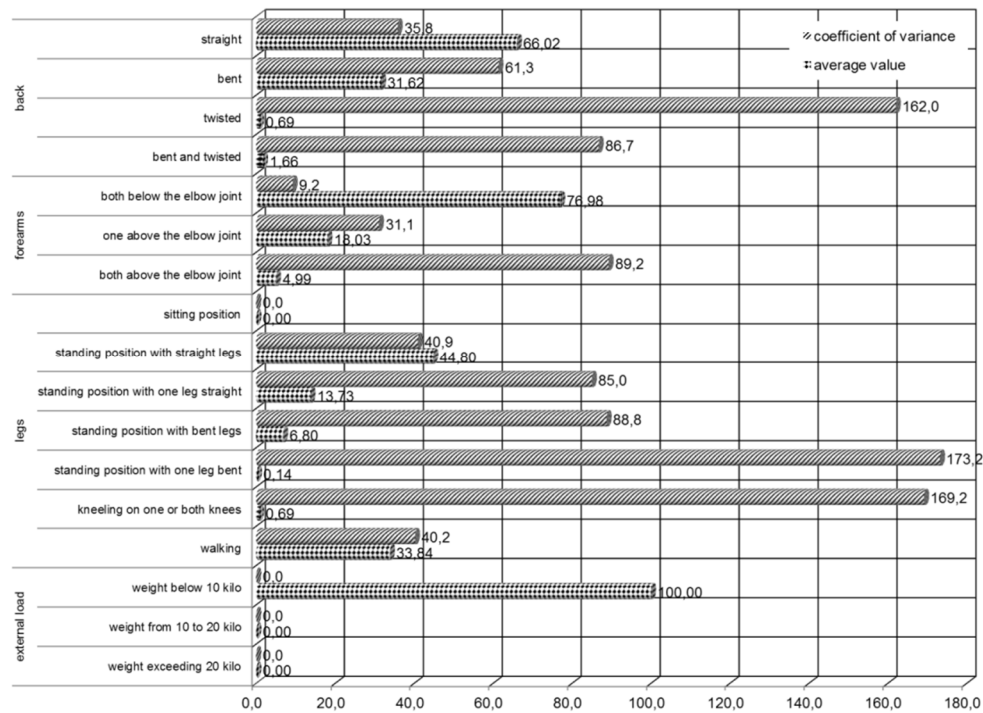


Figure 5. The time structure of maintaining a particular body position during a working day at the station operating a needling machine

Also, a high value of the coefficient of variance was reported at the standing position with one leg bent and it was 173% and the kneeling position amounting to 169% (fig.6). Although, the above-mentioned positions generally constitute a low percent in the structure of the shift working time, they constitute a significant threat for the workers' health and to a great extent depend on the subjective work technology and do not result from improper technology. It was reported that 27% of the working time, the workers' body position could be described with the code "1171" which stands for the worker's straight back, both forearms below the elbow joint, work performed during walking. This position was classified to the 1st category of assessing loading with the static work. It was reported that from among the body positions, described with codes classified to the 2nd category of loading, the most frequently, because as much as 9.7% the position described with the "2121" code, standing for the bent back, both forearms below the elbow joint, a standing position with straight legs, was reported. Whereas, from among the positions, described with the codes belonging to the 3rd category of loading, which constitute 6.1% of the total working time, the code "2141" was reported, which stands for the bent back, both forearms below the elbow joint, the standing position with bent legs. The longest activity, because as much as 83.2% of the time at the operation of the needling machine, consisted in controlling its working parameters (fig.6).

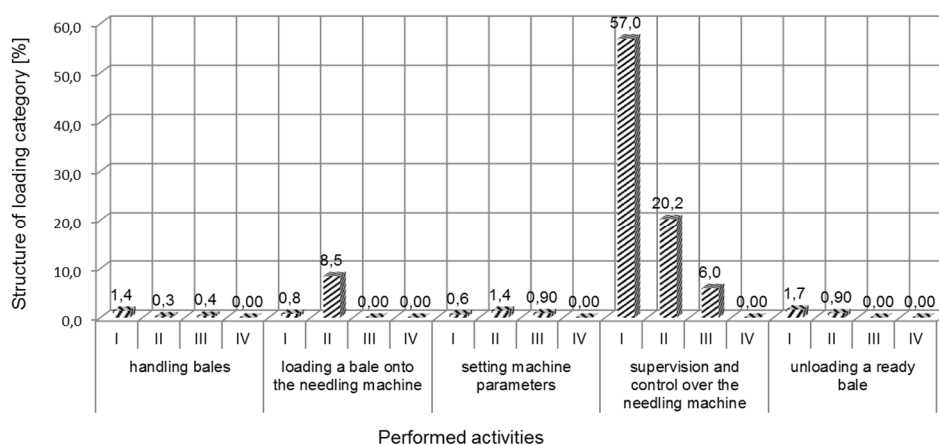


Figure 6. The structure of the category of loading during the performed activities at the station operating a needling machine

Whereas, the shortest activity in the structure of the shift time, which constituted only 2%, was carrying bales of non-woven fabric. The 1st category of loading with the static work prevailed at the station operating the needling machine and it was 61.5% of the shift time (fig. 8). It was stated that for over 30% of the working time, they took positions, which could have negatively influenced the musculoskeletal system (the 2nd category). Taking into consideration, the structure of categories of the reported loading, it was determined, that it was at the average level. The last but one stage of geotextile production consisted of activities related to its cutting and packing. It was reported that in case of cutting geotextile, this activity required a worker to keep his/her back straight for approx. 94.9 of the working time (fig.7). Whereas, for 83.7% of the shift time, a worker maintained forearms below the elbow joint and for 80.5%, straight legs and the standing position. \

From among all body positions reported during the research at the said working station, position prevailed (66.7% of the working time), which could be described with the code "1121" which meant that the worker's back were straight, both hands were below the elbow joint, legs were also straight and the weight of the handled material did not exceed 10 kilo. It was stated that approx. 95% of activities related to cutting geotextile performed by workers was placed in the 1st category of loading with the static work. The 2nd category of assessing the load constitutes 4.4% of the time for the performed activities. Whereas, the 3rd and 4th category of loading with the static work were not reported during the analysed working shifts. The final stage of the technology of geotextile production was packing the ready-made product in the plastic sleeve. During this activity (fig.8) the most often workers took a body position, which in case of a back stood for – a straight back (79.1%), in case of legs - the standing position (93.4% of the shift duration). Whereas, the activity, performed by a worker for 51.1% of the working time, required maintaining forearms above the elbow joint.

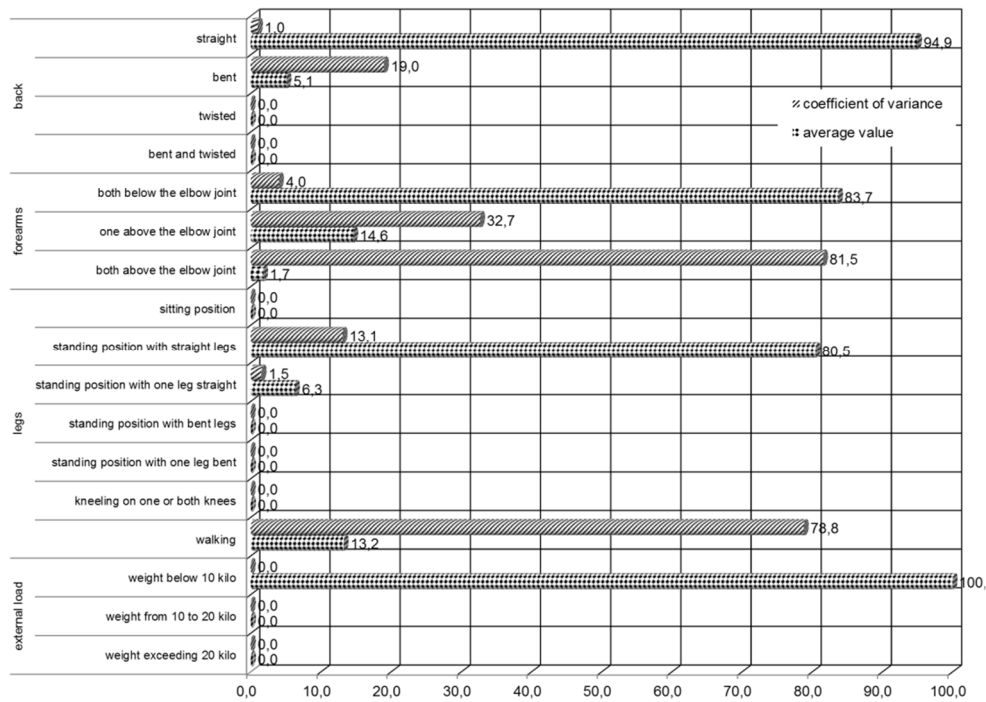


Figure 7. The time structure of maintaining a particular body position during a working day at the station of cutting geotextile

The most frequent position at this station may be described with the code "1321" (the worker's back straight, both forearms above the elbow joint, the standing position with straight legs), which generally constituted 54.9% in the structure of the working time classifying it to the 1st category of loading with the static work. In case of the second category of loading a worker with the static work, it was determined, that a position with the bent back and forearms below the elbow joint and straight legs was a prevailing and it was described with the code "2121", which constituted 24.2% of the total working time.

During packing a ready-made product the 1st category of assessing the static load prevailed in 72.5%. 26.37% of the working time belonged to the 2nd category, which forced out positions, which could have had a negative impact on the musculoskeletal system of a man. Taking into consideration the structure of the working time, loading with the static effort at this work station was classified as high.

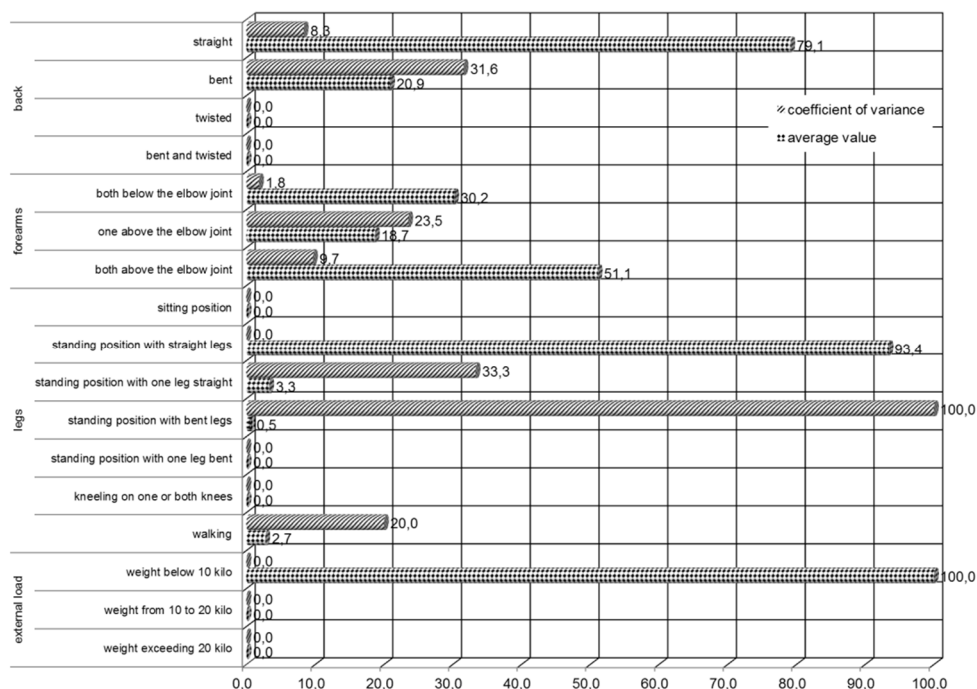


Figure 8. The time structure of maintaining a particular body position during a working day at the packing work station

Conclusion

1. The tests, which were carried out in the production establishment PCPW – Eko Karpaty, allowed determination of the size and structure of the static load of workers during work at the particular work stations. It was reported almost in all cases of stations, that loading with the static work was at the average level.
2. It was stated that at all work stations, which constitute a production line of geotextile, workers in majority, took a natural body position and their loading was at the acceptable level, classified to the 1st category of the static load. Loading employees with work, estimated with the OWAS method, at 4 out of 5 tested work stations, resulting from the category of the body position at work and duration of maintaining one position was classified as average loading and only in one case this loading was identified as high.

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ERGONOMICZNA OCENA OBCIĄŻENIA UKŁADU MIĘŚNIOWO-SZKIELETOWEGO PRACOWNIKÓW W PROCESIE PRODUKCJI GEOWŁÓKNINY

Streszczenie. Szacuje się, że w krajach europejskich ok. 27% osób pracuje przez więcej niż połowę czasu pracy w pozycji, która wywołuje zmęczenie i bóle mięśniowe mogące zakłócać koordynację postawy, co zwiększa ryzyko i możliwość popełnienia błędów przy obsłudze maszyny. Badania dotyczyły oszacowania ryzyka wystąpienia dolegliwości układu mięśniowo-szkieletowego pracowników operujących na poszczególnych stanowiskach roboczych stanowiących ciąg technologiczny do produkcji geowłókniny. Ponadto podjęto próbę korekcji organizacji pracy pozwalającej na minimalizację wpływu niekorzystnego układu posturalnego człowieka na jego zdrowie. Wykorzystując metodę „OWAS” (*Ovako Working Posture Analysis System*) określono wielkość oraz strukturę obciążenia układu mięśniowo szkieletowego pracowników. Odnotowano, że na wszystkich stanowiskach roboczych stanowiących przedmiot badań dominowała I kategoria oceny gdzie obciążenie pracą statyczną było średnie bądź duże, ale akceptowalne.

Słowa kluczowe: ergonomia, układ mięśniowo-szkieletowy, stanowisko pracy, metoda OWAS