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Joanna BARTNICKA
Silesian University of Technology
Institute of Production Engineering
joanna.bartnicka@polsl.pl
Damian GIZA
Jennmar International
damiangiza@o2.pl
Agnieszka ZIĘTKIEWICZ
Silesian University of Technology
Institute of Production Engineering
agnieszka.zietkiewicz@polsl.pl
Grzegorz KOWALSKI
Department of General Surgery and Endocrine Surgery
Specialist Hospital No. 2 in Bytom
kowalskig@onet.com.pl

# MUSCULOSKELETAL OCCUPATIONAL HAZARDS IN TWO CHALLENGING WORKING ENVIRONMENTS. A CASE STUDY FROM MINING INDUSTRY AND HEALTH CARE

**Summary.** The comparative study of working conditions in areas of mining industry and health care services in the area of MSDs is presented in the paper. The examined working environments are considered as demanding in terms of working organization as well as technical, communication and environmental aspects. Such circumstances need to use of specific rules and requirements for maintaining work safety of MSDs. Taking this as a background, a classification of the factors was defined in selected fields in order to make it possible to extract the similar assessment criteria. These were used to analyze the problem areas in terms of working conditions which influence on prevalence of MSDs. The analysis outcomes are the basis for seeking universal methods and tools supporting work safety assessment among mining workers and medical staff. As a case study, the working activities of mining excavations staff and surgical team members performing surgeries in an operating room were considered.

**Keywords:** MSDs, occupational risk, miners, surgeons, body posture, ergonomics.

# ZAGROŻENIA W UKŁADZIE MIĘŚNIOWO-SZKIELETOWYM PRACOWNIKÓW DWÓCH WYMAGAJĄCYCH ŚRODOWISK PRACY. STUDIUM PRZYPADKU Z OBSZARÓW GÓRNICTWA WĘGLA KAMIENNEGO I OCHRONY ZDROWIA

**Streszczenie.** W artykule zaprezentowano studia porównawcze, dotyczące warunków pracy w dwóch środowiskach: w górnictwie węgla kamiennego oraz w ochronie zdrowia. Środowiska poddane analizie nacechowane są wysokim stopniem ryzyka zawodowego, związanego z występowaniem schorzeń w układzie mięśniowo-szkieletowym. Tak zarysowane tło badań stanowiło podstawę do identyfikacji głównych problemów w zakresie ergonomii i pozycji ciała, a także określenie możliwych przyczyn i skutków występowania obciążeń posturalnych. Podstawą badań było dokonanie analizy porównawczej czynników technicznych i organizacyjnych kształtujących warunki pracy na stanowiskach górnika dołowego i chirurga laparoskopowego. Uzyskane wyniki badań, wydawać by się mogło w skrajnie różnych obszarach problemowych, dają podstawę do poszukiwania uniwersalnych metod i narzędzi wspomagających ocenę zagrożeń zdrowotnych.

**Słowa kluczowe:** układ mięśniowo-szkieletowy, ryzyko zawodowe, górnik, chirurg, pozycja ciała, ergonomia.

## 1. Introduction

The background for the research is based on many years of experience in the area of conducting ergonomics studies in both mining industry and health care. Working conditions in these specific environments are a cause of many adverse effects for employees. They are differentiated health risks, the results of which may be occupational or para-occupational diseases and in particular musculoskeletal disorders (MSDs). The problem of MSDs among medical staff and miners is particularly related to static overburden of their locomotor system. It is because of:

- specific working space conditions which is limited and isolated,
- demanding working environment, as regards Occupational Health and Safety regulations,
- the necessity of using protective clothing etc.

Often, these conditions determine nonphysiological and awkward body position of workers.

For instance there were recognized the epidemiological MSDs image of 1130 miners in one of Silesia coal mine. A half of them (514 miners) indicated MSDs symptoms, mainly low back pain (LBP). The structure of MSDs among the analyzed group of miners is presented in the Figure 1.

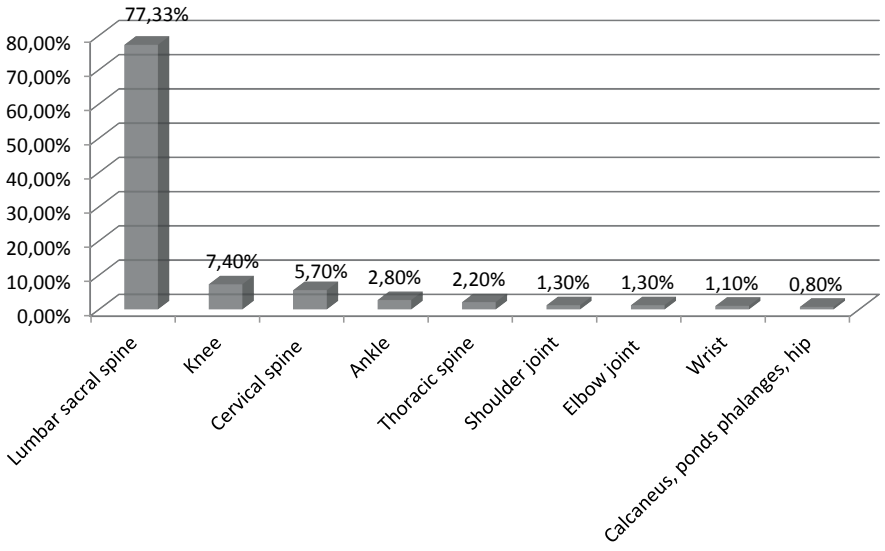



Fig. 1. The structure of MSDs among miners
Rys. 1. Rodzaje MSD występujące u górników
Source: Own elaboration.

The characteristic outcome of the study was that miners working without external loads suffer from the same disorders. Seemingly light operations, especially with a high degree of frequency, performed in awkward body position, can lead to accumulation of locomotor burdens, and in consequence to chronic MSDs. Particularly this applies to machine operating like mobile roof supports, locomotives or shearer loaders.

In hospitals the ergonomics deficiencies are similar. The awkward positions are especially recognized among minimal invasive surgeons, what is confirmed by own study on MSDs among laparoscopic surgeons. Particularly the ergonomic problems relating surgeons' burden is presented in the Figure 2.

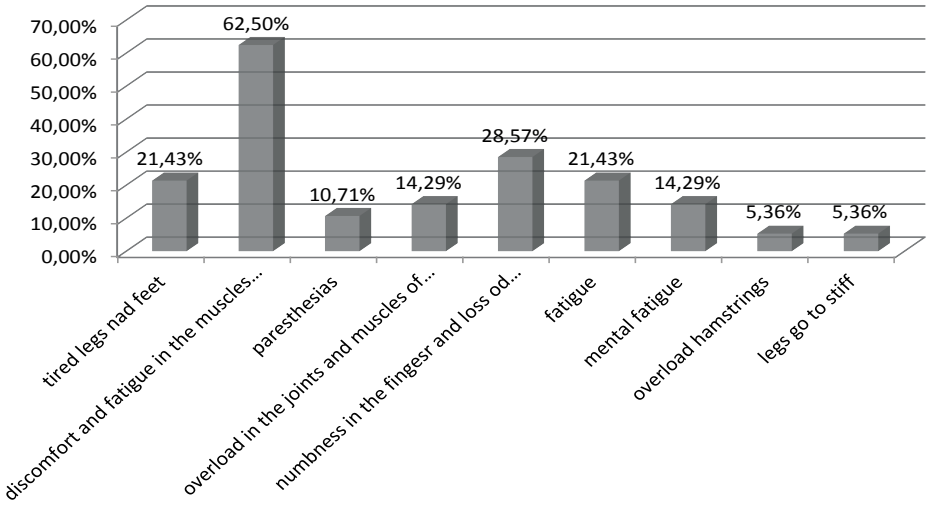



Fig. 2. The structure of MSDs ergonomic problems among laparoscopic surgeons
Rys. 2. Rodzaje dyskomfortu związanego z MSD u chirurgów laparoskopowych
Source: Own elaboration.

The literature of ergonomics in laparoscopic surgeries highlights the problem of static burden of surgeons. This problem refers to nonphysiological body position during surgeries with less amount of back movements and less range of motions [1]. The characteristic features are also uncomfortable, repeatedly movements of upper limbs and long-term static posture of the head and back [2]. In most cases surgeons are in standing position while performing laparoscopic operations and there is a risk of loss of stability. Indeed, they have the limited capacity for body load moving by themselves. They must act with high manually precision often standing on one leg and using feet to operate the pedals of laparoscopic devices [1, 3, 4]. In addition the design of laparoscopic tools and the ways of using them determine untypical positions of arms, hands and fingers [5].

All these factors relating to the body position of laparoscopic surgeon can take the form of health risks, especially for musculoskeletal system, which include (a) the awkward and uncomfortable postures in which the operations are done by a long period of time, (b) the repeatability of operations. The literature draws attention to the consequences of the occurrence of such risks, including musculoskeletal system burdens [6, 7, 8, 9], the neuromusculoskeletal disorders [10]; discomfort and paresthesia of hands and formation within them injuries and nerve irritation [5, 11].

The compilation of knowledge on the risks while performing work operations by miners and surgeons allows the authors for defining the common problem areas concerning body posture ergonomics and adopt similar research methodology for examine working conditions.

## 2. The objective, material and methods

The aim of the research was to conduct ergonomic assessment and compare the impact of ergonomic factors shaping the working postures at selected work stations in the mining industry and health care.

The object of the study were:

- machine operator and installation of harrow conveyer sections located in selected coal mine,
- surgeon performing laparoscopic surgery in selected hospital.

The examined objects are located in Silesia region in Poland.

There were defined research assumptions which were the selection of criteria for performing comparative analysis:

1) the criteria relating to the employee: (1a) sex – male, (1b) dominant position – standing,
2) the criteria relating to the working conditions: (2a) work organization – limited work space, the need for protective clothing, (2b) equipment – using the tools or operating machinery, (2c) external load – from 0 to 5 kg.

The research methodology was divided into 3 main stages:

S1. The acquisition of research material.

S2. The collection and processing of research data.

S3. The ergonomic assessment and outcomes analysis.

The acquisition of research material was done by following methods: an interviews with the experts in the field of the specific working conditions in mining industry and health care and examination of work stations based on assumed research criteria, than the selection of the position for ergonomic analysis. In addition the aim of the interviews was to acquire knowledge about the specific conditions for research with the use of observation methods and photo registrations of the specificities of the work environment. According to the interview outcomes there were performed observations and photo registrations of selected working processes in coal-mine and operating room.

The collection and processing research data was performed with the use of two computer tools:

1. 3DSSPP (Three Dimensional Static Strength Prediction Program) [12] based on photo registrations. 3D SSPP which enables human body modeling based on recorded worker's body position. The human body model is a pattern of momentary body position which is defined by certain body segment angles (Fig. 3).
2. REBA method for MSDs and risk assessment. REBA method was developed by Dr. Sue Hignett and Dr. Lynn McAtamney, ergonomists from University of Nottingham in England. REBA is a postural targeting method for estimating the risks of work-related entire body disorders. A REBA assessment gives a quick and systematic assessment of the complete body postural risks to a worker. For each region, there is a posture scoring scale plus adjustment notes for additional considerations [13] (Fig. 4).

Additionally the research was complimented by simulation analysis of MSDs ergonomic assessment incorporating different variants of the external load for coal-mine work stations.

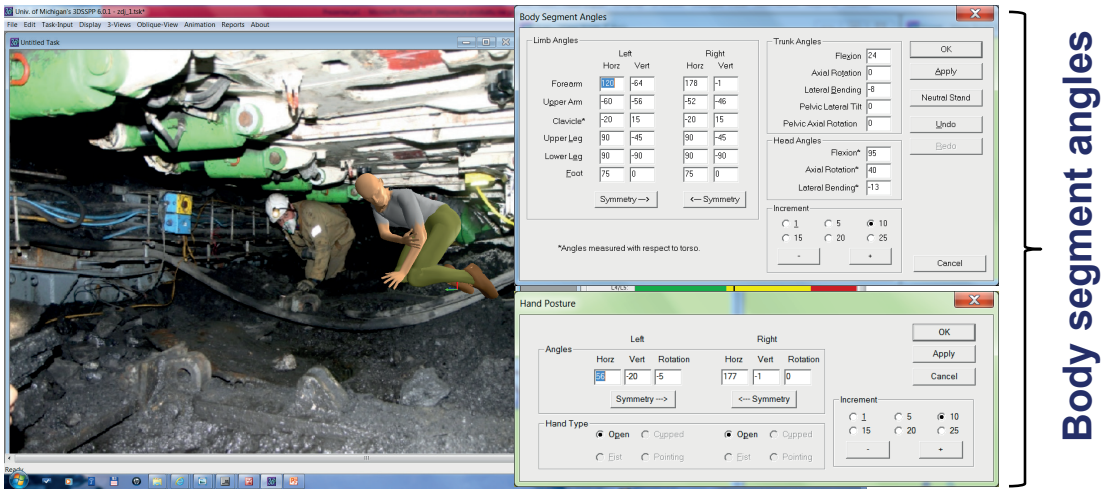



Fig. 3. The way of body segment angles identification
Rys. 3. Sposób określenia kątów nachyleń części ciała
Source: Own elaboration.

The Figure 4 presents the location of these body segments angles which are the input data for REBA method.

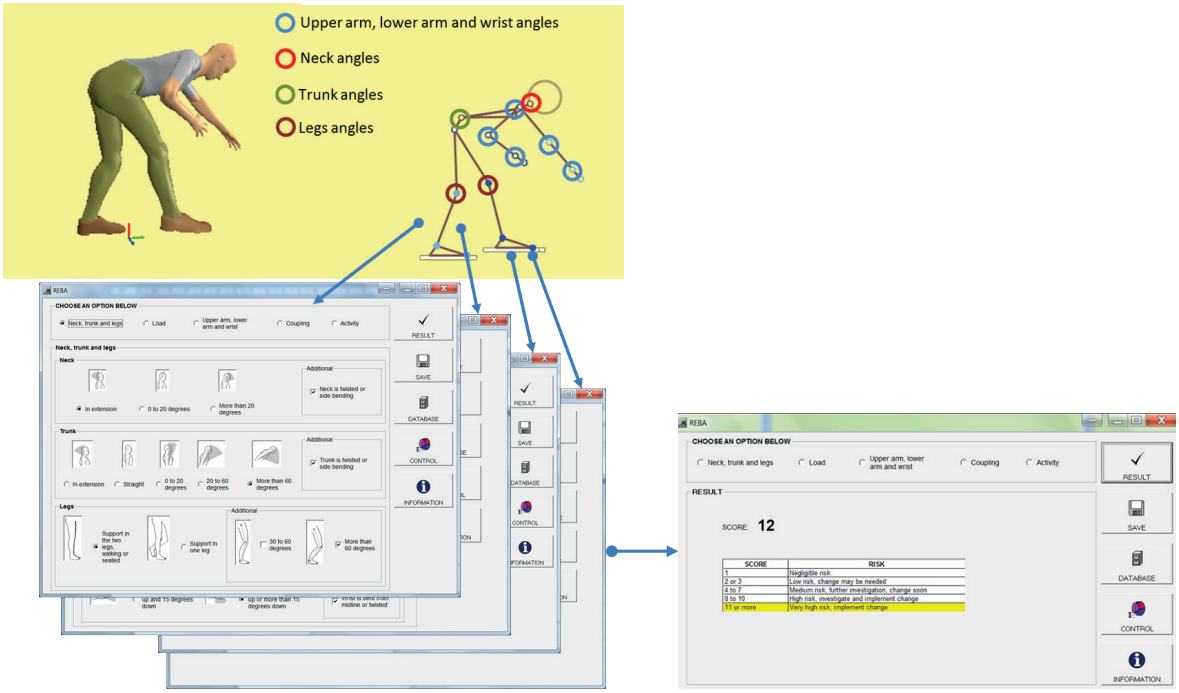



Fig. 4. The graphical interpretation of REBA method
Rys. 4. Graficzna interpretacja metody REBA
Source: Own elaboration.

Interpretation of REBA risk assessment result is presented in the Table 1.

Table 1

Interpretation of risk assessment result

| SCORE | RISK |
|---|---|
| 1 | Negligible risk |
| 2 or 3 | Low risk, change may be needed |
| 4 to 7 | Medium risk, further investigation, change soon |
| 8 to 10 | High risk, investigate and implement change |
| 11 or more | Very high risk, implement change |

Source: [14]

## 3. Research outcomes and discussion

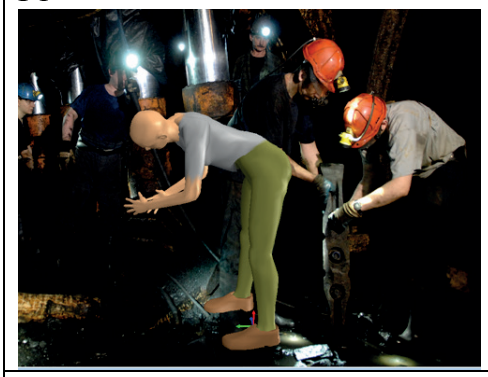
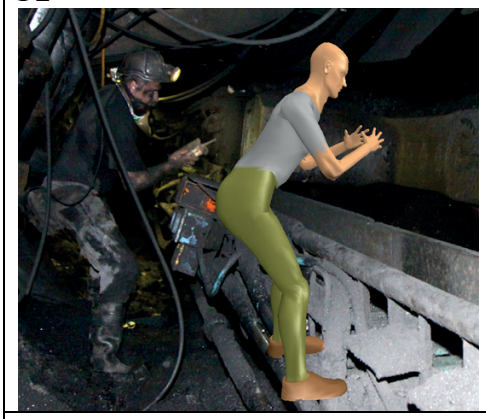
There were selected four different body postures per each environment from the research material. The selected activities were indicated by two similar factors:

– One or more body parts were held for longer than 1 minute.
– There were characterized by small range actions more than 4 times per minute.

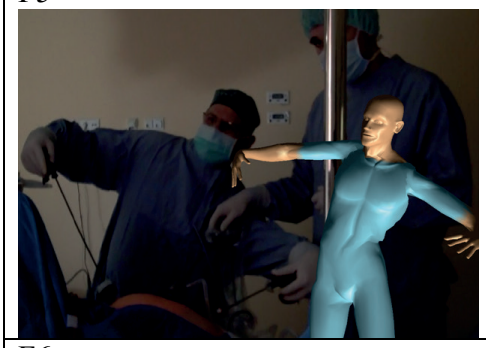
Table 2 presents the hybrid photo developed with the use of 3D SSPP as well as main data defining body postures and risk score in REBA.

Table 2

Body posture ergonomic assessment

| Hybrid photo of body posture | neck | trunk | legs | upper arm | lower arm | wrist | REBA score |
|---|---|---|---|---|---|---|---|
| F1  | 0 to 20 degrees | more than 60 degrees | 30 to 60 digress | -20 to 20 degrees | 60 to 100 degrees | between 15 degrees up and 15 degrees down | 9 |
| F2  | in extension | 20 to 60 degrees | 30 to 60 degrees | 20 to 45 degrees | 0 to 60 degrees | between 15 degrees up and 15 degrees down | 7 |
| F3  | more than 20 degrees | more than 60 degrees | 30 to 60 digress | 45 to 90 degrees | 60 to 100 degrees | More than 15 degrees up or more than 15 degrees down | 9 |

cont. of table 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F4  | in extension | more than 60 degrees | 30 to 60 digress | 45 to 90 degrees | 0 to 60 degrees or more than 100 degrees | More than 15 degrees up or more than 15 degrees down | 10 |
| F5  | more than 20 degrees | 0 to 20 degrees | 30 to 60 digress | 45 to 90 degrees | 0 to 60 degrees or more than 100 degrees | More than 15 degrees up or more than 15 degrees down | 11 |
| F6  | in extension | more than 60 degrees | 30 to 60 digress | 20 to 45 degrees | 0 to 60 degrees or more than 100 degrees | More than 15 degrees up or more than 15 degrees down | 11 |
| F7  | in extension | 20 to 60 degrees | 30 to 60 digress | 20 to 45 degrees | 0 to 60 degrees or more than 100 degrees | More than 15 degrees up or more than 15 degrees down | 10 |

cont. of table 2

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F8  | in extension | 20 to 60 degrees | 30 to 60 digress | 20 to 45 degrees | 0 to 60 degrees or more than 100 degrees | More than 15 degrees up or more than 15 degrees down | 11 |

Source: Own elaboration.

The primary assumption of the research for this paper was to investigate the possibility of using similar observational methods and tools for risk assessment in both: working environments of miner and surgeon. The reasons for the examination of these so different working activities were the results of the previous study of authors conducted in the field of ergonomics and work organization. The previous analysis conducted separately in the mining industry and health care showed similar difficulties in the research methodology and analysis process. On this basis, the classification of problem areas in three domains: organizational, technical and environmental, was made. The examples of this are: difficulties in obtaining the research material due to the high degree of working processes complexity, the limited work spaces, the high safety and sanitary requirements, poor work lighting etc.

Therefore, in order to make a comparative analysis of working environment for miner and surgeon, there was assumed that the basis for the ergonomic evaluation of static burden is body position and activities without any additional external loads. The analysis showed that in seven (F1, F3, F4, F5, F6, F7, F8) out of eight surveyed cases, the risk of MSDs is on high or very high level. At this point it should be paid attention to the fact that on each of these seven positions the dominated posture is deep flexion of the trunk and further trunk and neck rotations. However, the higher scores for surgeon is the result of additional extreme wrists positions caused by the construction of laparoscopic tools.

Next, the analysis showed that one case of the mining area (F2) has a medium risk. The position is determined only by reduced height of excavation, and is not enforced by the manual operations or design of the tool.

The research outcomes, indicating that, by exclusion of external load, surgeons have higher risk score than miners, encouraged the authors to take additional complementary analysis. For this purpose there were carried out simulation studies for each of the four miners' activities (F1, F2, F3, F4), this time taking into account additional external load of 5 to 10 kg and over 10 kg. The outcomes of risk scores for new assumptions are presented in the Table 3.

Table 3

Risk assessment result for miners including external load

| Miners' activities | Score for load 5 to 10 kg | Score for load over 10 kg |
|---|---|---|
| F1 | 11 | 12 |
| F2 | 10 | 11 |
| F3 | 11 | 12 |
| F4 | 12 | 13 |

Source: Own elaboration.

Inclusion of an additional variable that is external load clearly showed a radical increasing risk score in the group of miners even at 4 scores. The example is the analysis of the working position the miner designated as F2. In the previous analysis, which does not take into account external load there was classified the risk of this position as a category at the medium level while taking into account the additional load the risk can be defined as high or very high.

It should be highlighted that the mining industry is more dynamic as regards the use of external loads and hence contains more variables for body postures assessment outcomes.

The important is the fact that in this type of research it should be analyzed the most critical factors affecting the working conditions. In the study, where only body position is taken into account, could distort the real picture of occupational risk.

On the other hand, the activities carried out without external load in other environments than mining, like laparoscopic surgeons' environment, also can demonstrate the same extreme values of occupational risk. The factor that determines the result is a criterion of the environment e.g. a limited working space or a technical criterion like the design of surgical instruments. As has been proven in the primary analysis of this article, these criteria cause extreme body positions especially in hands and neck.

Conducting ergonomic analysis on workplaces in the so-called specific and limited working conditions requires the inclusion in the work process and the analyzed working environments tools and machines since they determine the employee' body position. In contrast, the frequency of operations with the use of machinery and equipment resources, directly affects the incidence of MSDs, which is confirmed by this study.

Regarding the methodology presented in this paper with its relation to studies conducting in different countries and demonstrated within the world literature it can be stated that the methods for ergonomic assessment are mostly classical and are based on observational procedures like OWAS, RULA or REBA. The popularity of them results from their universal states and the utility in many different occupational groups. More sophisticated ergonomic methods including motion capture technology are present in research conducted in laboratory conditions. In this paper these observational methods were used due to their universality and in the same time were integrated with computer and more advanced tool i.e. 3D SSPP.

With reference to the MSDs issues in coal mine workers there was noted little research, inter alia described in [15, 16, 17, 18, 19]. Simultaneously, there are no studies in library databases that take into account the research aim of this paper.

## 4. Conclusion

There were recognized typical body postures of miners and laparoscopic surgeons in the study. All of investigated postures (apart of one case among miners workstations) were scored as high or very high risk of MSDs what requires the necessity of changes in workstations.

The dominance of very high risk of surgeon is caused by the need of using precision surgical tools and operating with a high manual precision what determines additionally the twisted and bending positions of surgeon's neck, trunk and wrists.

The risk of miners MSDs is emphasized by the high degree of operations frequency and the use of external loads. However an assumption of the research was to analyze tasks with external loads 0 to 5 kg for creating common basis for research it two different environments.

The preliminary research proves that so different work (mental work and physical work) can be investigated with the use of similar tools. There are also indicated the similar organizational problems of doing research, e.g. acquisition the material, due to the specificity and limitations of the tested environments.

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**Omówienie**

W artykule przedstawiono wyniki wstępnych badań nad tworzeniem i wykorzystaniem podobnej metodologii oceny postawy ciała w skrajnie różnych warunkach pracy, tj. w górnictwie i opiece zdrowotnej. Wskazano podobieństwa i różnice dotyczące powodów niewygodnych pozycji pracy i oceny ryzyka. Analogicznym czynnikiem powodującym MSD w obu środowiskach jest ograniczona przestrzeń robocza. W przeciwieństwie do górników, w pracy chirurgów nie istnieje żadne obciążenie zewnętrzne sterowane przez chirurga. Jednak wynik zagrożenia dla górników wykonujących pracę z obciążeń zewnętrznych i chirurgów jest podobny i na bardzo wysokim poziomie.