

Ravindra S. Goonetilleke
Waldemar Karwowski *Editors*

Advances in Physical Ergonomics and Human Factors

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Advances in Human Factors and Ergonomics 2019

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Proceedings of the AHFE 2019 International Conference on Physical Ergonomics
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Preface

The discipline of human factors and ergonomics (HF/E) is concerned with the design of products, process, services and work systems to assure their productive, safe and satisfying use by people. Physical ergonomics involves the design of working environments to fit human physical abilities. By understanding the constraints and capabilities of the human body and mind, we can design products, services and environments that are effective, reliable, safe and comfortable for everyday use. A thorough understanding of the physical characteristics of a wide range of people is essential in the development of consumer products and systems. Human performance data serve as valuable information to designers and help ensure that the final products will fit the targeted population of end users. Mastering physical ergonomics and safety engineering concepts is fundamental to the creation of products and systems that people can use, avoidance of stresses and minimization of the risk for accidents. This book focuses on the advances in the physical HF/E, which are a critical aspect in the design of any human-centered technological system. The ideas and practical solutions described in this book are the outcomes of dedicated research by academics and practitioners aiming to advance theory and practice in this dynamic and all-encompassing discipline. A total of six sections are presented in this book:

- Section 1 Physical ergonomics and work-related musculoskeletal disorders
- Section 2 Physical ergonomics and comfort
- Section 3 Design, anthropometry and posture
- Section 4 New trends of development and application of risk analyses methods in the strategy of Industry 4.0
- Section 5 Design for people
- Section 6 Ergonomics design of wearables

Each section contains research papers that have been reviewed by the members of the international editorial board. Our sincere thanks and appreciation to Board Members as listed below:

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We hope that this book, which is the international state of the art in the physical domain of human factors, will be a valuable source of theoretical and applied knowledge enabling the human-centered design of a variety of products, services and systems for global markets.

July 2019

Ravindra S. Goonetilleke
Waldemar Karwowski

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Physical Ergonomics and Work-Related Musculoskeletal Disorders



Deep Learning Model to Recognize the Different Progression Condition Patterns of Manual Wheelchair Users for Prevention of Shoulder Pain

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Abstract. Wheelchair user will use different propulsion strategies to control in a variety of progression conditions that may induce the shoulder pain. The hypothesis of this study is that wheelchair user in different progression conditions has different ways to control the wheelchair. The purpose of this study is to use the accelerometer to recognize the movement of the wheelchair. It can be easily used to define the different progression condition in order to know the cause of the inducement of shoulder pain. The researchers collected acceleration data during the wheelchair progression in rough and smooth distinguishing surfaces: (1) outdoor grassland and; (2) indoor flatland. Researchers transformed the acceleration data into spectrogram files and training convolutional neural network (CNN) deep learning model to accurately recognize and predict wheelchair user's wheelchair location. As the results, the wheelchair user's medial-lateral direction of acceleration is expected to present more significant features than the front-back motion when being related to progression condition. At the same time, the vertical direction of acceleration also reflected the wheelchair vibration during different surface of progression condition.

Keywords: Propulsion strategy · Acceleration · Spectrogram · Convolutional neural network

1 Introduction

Wheelchair users rely on the manual wheelchair to restore daily mobility. Shoulder pain in manual wheelchair users with paraplegia is very common. Their shoulders unavoidably overuse both arms to propel and control the wheelchair. During the previous report, there are around 50% to 70% of patients who use manual wheelchairs and experienced upper limb pain [1]. The wheelchair user shoulder joint carry more pressure related to the resistance force of the propulsion over the rough pathway. These users may often feel that they have too much weight on their shoulders and this leads them to having shoulder pain.

Shoulder pain could bring more complicated problems in the shoulder joint. The shoulders could bear the weights by receiving too much pressure across the subacromial area during the manual control of the wheelchair [2]. It also shows that wheelchair user's shoulder pressure significantly relates to increasing the crisis of acromioclavicular joint edema or coracoacromial ligament thickening [3]. While the other report shows that over usage of the shoulder could increase the damage at high compression forces on the glenohumeral joint heavy loading on rotator cuff muscles, the subacromial bursa, and tendinopathy [1, 4].

It is more important to understand that manual wheelchair users propel and control in their living environment. It could be in any way and progression surface that they run over with the wheelchair, either on the bumps, ramps, and rough surface of the pathway.

The related studies report that wearable sensors have been used to detect and collect the data of human or mobility behavior then processed by the programmable classification [5, 6]. The accelerometer records the velocity change rate of the wheelchair that is separated by x-y-z axial vector quantity. As previously mentioned on the report, it has been said that they collected human activity data by attaching the accelerometer on the external limbs [6]. The extracted and obtained features from each of the axis signals of accelerometer are turning into acceleration-magnitude signal, and it is usually being expressed in time-domain signal. Furthermore, the coordinate acceleration expresses the object movement with vibration, rotation, and falling.

The time-domain signal is not directly referring to the specific movement or position [7]. They use time-domain signal data of accelerometer to train convolutional neural network (CNN) and recognize the human activity pattern. In deep learning, CNN is a class of deep neural networks, most commonly applies to analyze visual imagery. However, it is difficult to provide suitable graphic features to satisfy training CNN for time-domain signal. In the end, a spectrogram may use for CNN to gather visual representation of the spectrum of frequencies of a signal as it varies with time.

The hypothesis of this study is that training model may have high accuracy to classify the different progression condition for a variety of propulsion strategy. The purpose of this study is to understand how the propulsion strategy affects the shoulder pain in relation to the acceleration.

2 Methods

To implement the researchers' study and verify the hypothesis, researchers expect to build a novel method for predicting propulsion strategy by dynamic data. There were two distinguishing features of wheelchair progression condition that were used in this study. First is indoor flatland to feature smooth surface while the other is outdoor grassland to feature the rough surface. They were used to collect acceleration of dynamic data and process deep learning for classification of the two distinguishing features.

It could capture and induce each axis of acceleration data to process visual recognition to find out which axis that is most related to wheelchair user's propulsion strategy. At the end of the study, the spectrogram has been used for clearer visual representation. The result summarizes the different propulsion strategies to influence shoulder pain (Fig. 1).

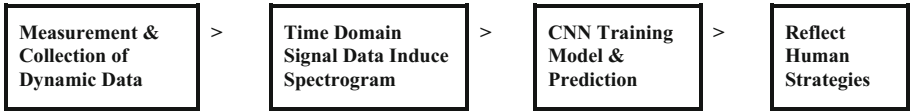


Fig. 1. Methodology diagram for the CNN model in preventing shoulder pain.

2.1 Subject of the Study

The researchers recruited a normal subject (male, 49 years old, 176 cm, 77 kg, no shoulder pain or upper limbs injury history) to understand X, Y and Z axis of accelerometer data about manual wheelchair user's propulsion strategy. The researchers also described the purpose of the experiment to the subject and informed him to use both hands to propel a manual wheelchair.

For collecting data in propulsion wheelchair, two distinguishing features have been used for progression condition. Researchers set up two locations which both size is 1350 x 550 cm. The subject propelled the wheelchair along the rectangular area moving non-stop with counter-clockwise direction until 20 min (Fig. 2).

(A) Indoor flatland



(B) Outdoor grassland

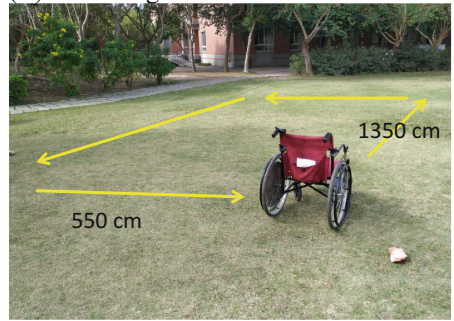


Fig. 2. Distinguishing features for progression condition in this study. (A) Indoor flatland and; (B) Outdoor grassland.

2.2 Device Setting and Data Collection

To easily utilize the convenience trend, researchers used the smartphone with an accelerometer that contains the microchip (Bosch BMI120, LGA package $2.5 \times 3.0 \times 0.8 \text{ mm}^3$) to measure different axial acceleration. Then, researchers also set the smartphone horizontally attached on the left armrest of manual wheelchair for acceleration data collection (Fig. 3). The smartphone position refers to the accelerometer direction including medial-lateral (x-axis), front-back (y-axis), vertical (z-axis) with unit timestamp. The accelerometer set the acquisition rate at 40 Hz.

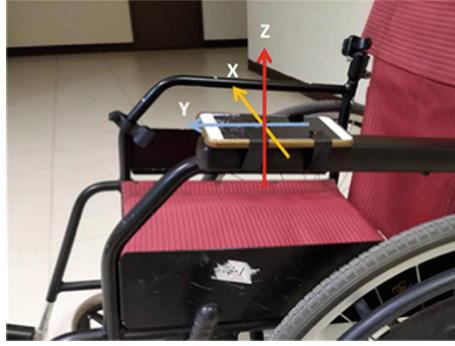


Fig. 3. Smartphone horizontal attached on left armrest of manual wheelchair to collect accelerometer data. The wheelchair front direction is y-axis of the accelerometer.

2.3 Data Augmentation

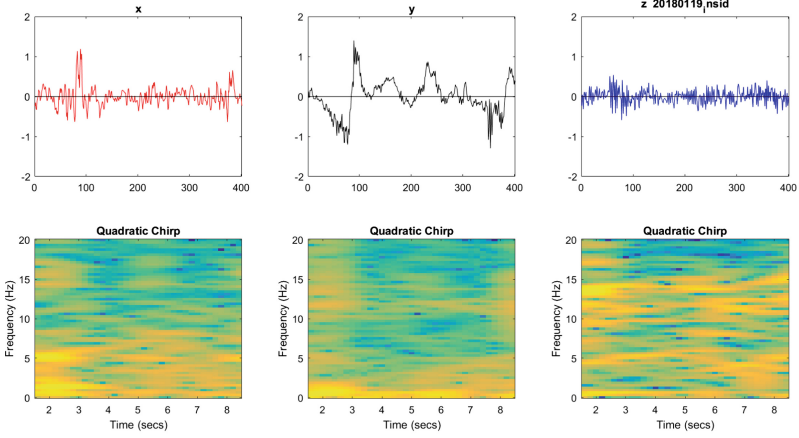
These time domain signal data are the raw data of acceleration. They have to undergo visual processing before researchers recognize training CNN as a model [6]. The wheelchair accelerometer data were separated and extracted to single x-axis, y-axis and z-axis data into two distinguishing features of “outdoor grassland” and “indoor flatland” (Fig. 4).

Then researchers extracted and separated the 5 and 10-s as a process from each group accelerometer data as a single graphic for the wheelchair propulsion feature. The spectrogram is a visual file for providing more features to the CNN training model. Although, researchers got these spectrogram files and the file quantities are not enough to train CNN model. For solving this situation, researchers resized the spectrogram images and added them to increase the number of images into the small dataset [8].

2.4 CNN Classification and Recognition

The study’s CNN model follows the architecture of AlexNet to build classification model of manual wheelchair progression condition. Researchers used five convolution layers (Activation function: ReLU) with max pooling layers and two fully-connected layers under Tensorflow structure by Python. One advantage of using Tensorflow and Python is that the model could use both central processing unit (CPU) and graphics

(A) Indoor flatland



(B) Outdoor grassland

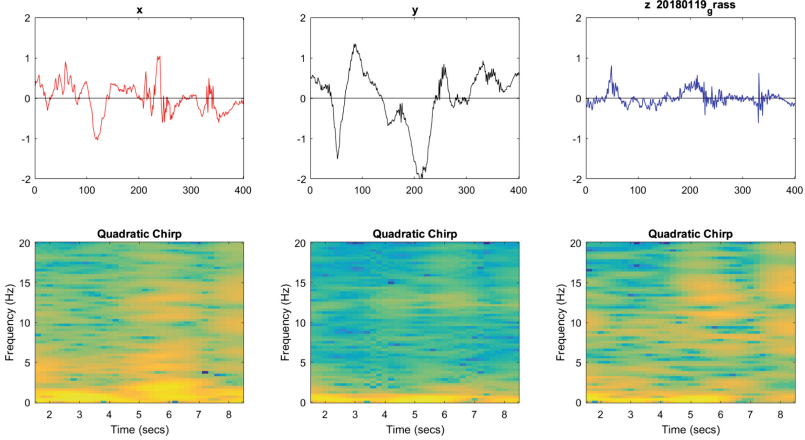


Fig. 4. The X, Y, and Z axis 10-s data transform into the single spectrogram. Each spectrogram is a visual data for CNN training. (A) Indoor flatland and; (B) Outdoor grassland.

processing unit (GPU) to feed the training data of minibatch into convolution layers and distributed into GPU to speed up training time for processing large number calculation of visual recognition [9] (Fig. 5).

This model runs 100-epoch to train with minibatch size 128 of the dataset. Researchers set the function of dropout rate at 80% increase training speed. It could use the one-hot function to encode and convert the images for calculating cross-entropy. After that, researchers used the Adam optimizer to make the learning rate more stable and efficient [10].

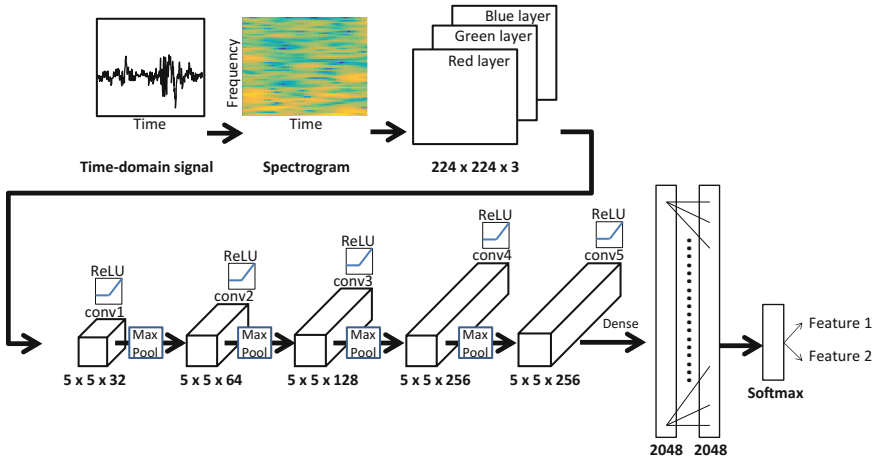


Fig. 5. The study follows AlexNet architecture to build convolutional neural network (CNN) model to classify the images.

3 Results

It transforms each of the X, Y, and Z axis accelerometer data into a single spectrogram. There are 1,440 files of 5-s and 720 files of 10-s acceleration data that have been generated to the spectrogram then have been resized for data augmentation. The spectrogram contains visual data to increase the recognition features.

The researchers trained the CNN model to recognize the spectrogram of “outdoor grassland” and “indoor flatland” in each dataset of x-axis, y-axis, z-axis, and x-y-z axis. The model runs entire epoch to learn these spectrogram features. Furthermore, researchers observed the loss function value in every training epoch. The model training also loss function in approaching to zero that presents a good learning rate (Fig. 6).

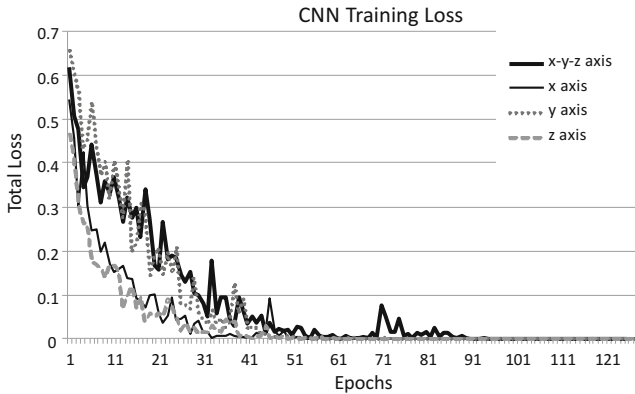


Fig. 6. The diagram shows the loss function value in approach to zero in each dataset of the axes.

The results of training CNN model have been generated to recognize wheelchair progression condition. After training and validation, the model could learn to classify the spectrogram into “outdoor grassland” or “indoor flatland”. The validation accuracy of x-axis, y-axis, z-axis, and x-y-z axis are 83.3%, 70.2%, 85.8% and 78.1%, separately (Table 1). These results matched our hypothesis that training model can classify the different progression condition for a variety of propulsion strategy. Therefore, the feature of x-axis (medial-lateral direction) is more distinguished than y-axis (front-back direction).

Table 1. The results of CNN training model

	Flatland/Grass			
Axis	x	y	z	x-y-z
Loss	0.000005	0.000049	0.000005	0.000042
Validate accuracy	83.3%	70.2%	85.8%	78.1%

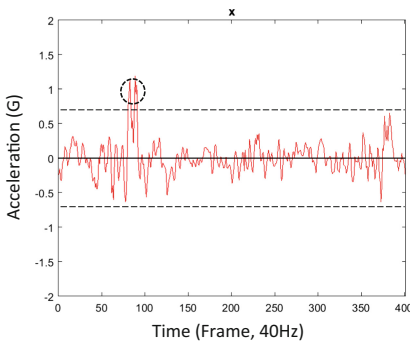
Note: accelerometer direction including medial-lateral (x-axis), front-back (y-axis), vertical (z-axis).

4 Discussion

The experiment shows that manual wheelchair really caused shoulder pain to the users. However, as the hypothesis stated, CNN training model can classify the different progression condition for a variety of propulsion strategy to help wheelchair users lessen the joint pain. At the end, the medial-lateral direction (x-axis, 83.3%) provides more accurate results than front-back direction (y-axis, 70.2%). The “outdoor grassland” wave peaks’ number are obviously more than the “indoor flatland.”

Researchers examined the acceleration diagram that showed the wheelchair progression condition. The medial-lateral acceleration does not just show the dramatic vibration but is also related to the propulsion with left-right force on a certain period of time (Fig. 7).

(A) Indoor flatland



(B) Outdoor grassland

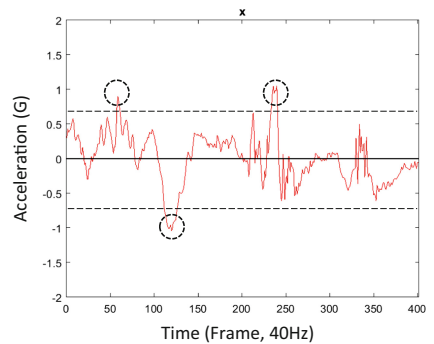


Fig. 7. A representative of the medial-lateral direction 10-s results. There are three wave peaks over acceleration at “outdoor grassland” while only one for “indoor flatland.”

The medial-lateral acceleration might reflect shoulder pain crisis that refers to wheelchair user's keeping of the correct direction for the propulsion on different progression condition. It could also refer to the wheelchair user's having to use extra power in the balance of both arms.

The balance is important for the wheelchair progression. The user exerts more effort in his shoulder for a careful control progression in rough surface like grassland. This causes the user to control the wheelchair moving forward in a balanced state (Fig. 8).

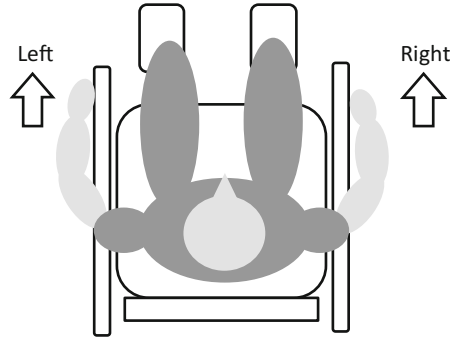


Fig. 8. The wheelchair user uses both arms to propel the wheelchair to control the wheelchair moving forward in a balanced state.

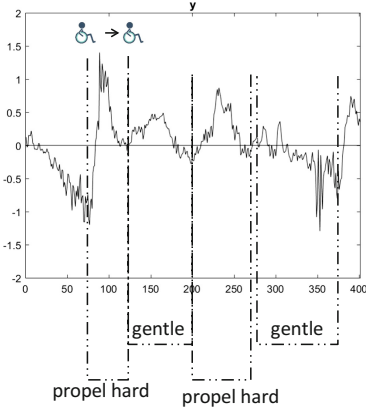
The wheelchair user exposed a situation of the shoulder pain risk that causes shoulder joint to wear and tear as stated in the previous study [11].

The peak acceleration of front-back direction (y-axis) showed the wheelchair forward propulsion. Researchers have seen the different waveform diagrams between “outdoor grassland” and “indoor flatland.” These front-back direction diagrams could also represent the wheelchair progression condition. When the wheelchair has been propelled at “outdoor grassland,” user may use more time to roll forward in the push rim (Fig. 9). Wheelchair user may use different propulsion strategy to move forward in different distinguishing feature of progression condition.

The status of vertical acceleration (z-axis) refers to wheelchair vibration in different progression condition. When the wheelchair propelled at “outdoor grassland,” it may have more vibrations than “indoor flatland” (Fig. 10). The deep learning of CNN has a higher accuracy in vertical acceleration, that means it may recognize rough or smooth surface by the magnitude vibration of wheelchair in progression.

In the different locations, the wheelchair user's propulsion strategy refers to carefully controlling of the wheelchair in forward direction with the use of upper limbs. The limitation of this study is that researchers only included a normal subject. As this is a preliminary study, researchers focused on using a wearable smart device for building the method. In the future work, researchers will recruit wheelchair user with shoulder pain for advanced study. These methods can be used in the future for clinical field study to profile the wheelchair user's propulsion strategy in relation with Wheelchair User's Shoulder Pain Index (WUSPI) or Brief Pain Inventory (BPI) [12]. Using the

(A) Indoor flatland



(B) Outdoor grassland

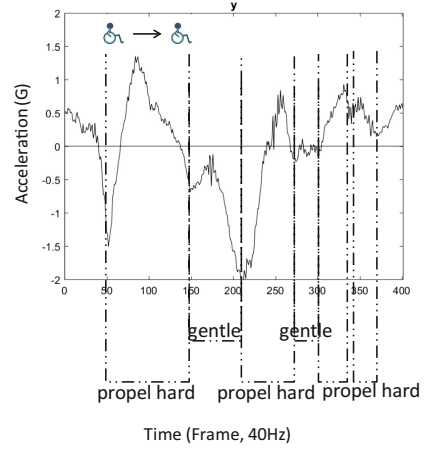
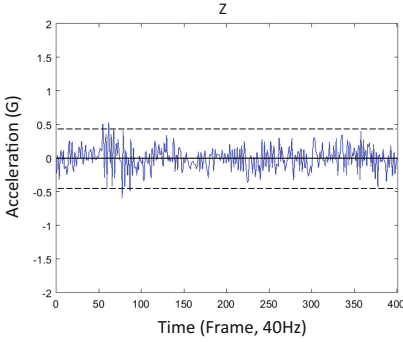


Fig. 9. A representative of the front-back direction 10-s results. There are four repeated times of hard propulsion over acceleration at “outdoor grassland” while two only for “indoor flatland.”

(A) Indoor flatland



(B) Outdoor grassland

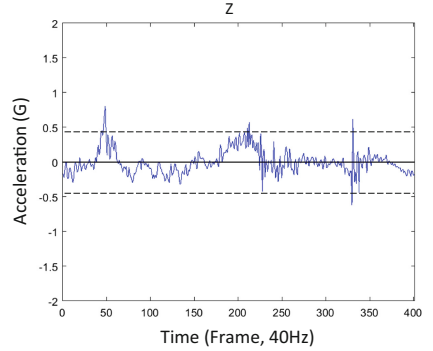


Fig. 10. A representative of the vertical direction 10-s results. There is more vibration over the acceleration at “outdoor grassland” than “indoor flatland.”

mobile or wearable smart device, more studies and applications would be developed on human activity recognition including health control, aging monitoring and preventive medicine.

5 Conclusion

Although this is a preliminary study, researchers have trained CNN model to recognize the untrained spectrogram of wheelchair progression condition and predict the location as well. It has been found out that each axis could represent different characteristics.

This study does not only intend to develop a method to use a smartphone with the accelerometer to collect wheelchair user's dynamic data. This study also discovered that the medial-lateral direction of acceleration is more accurate than front-back direction in the CNN model to recognize the feature. The vertical direction of acceleration can get the vibration of the wheelchair in distinguishing surface.

In conclusion, the propulsion strategy in wheelchair users may focus on the medial-lateral direction to carefully control the wheelchair in different progression condition.

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Physical Workload Analysis in Processing Operations: Metal Processing Manufacturing

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Abstract. The aim of this study is to perform physical workload analysis in metal processing industry operations (assembly operators, packaging operators and inspection staff) using objective ergonomics research methods based on the heart rate monitoring and muscle fatigue. The study was carried out in a medium sized metal manufacturing enterprise in Latvia in the department of manufacturing of ironing boards. Assembly, packaging operators and inspection staff agreed to take part in the objective heart rate monitoring and muscle myotonometry measurements. Results show that workers are at high risk of developing WMSDs, since they are subjected to heavy manual work and load on muscles during work. Accordingly to the heart rate analysis the assembly operators and packing operators can be subdivided into heavy work category, but inspection staff- in moderately heavy category. Myotonometry investigation results confirm muscle fatigue and heaviness of physical workload.

Keywords: Production · Operators · Heart rate · Miotonometry

1 Introduction

Processing industry is one of the leading industries of Latvian economy. The number of WRMSDs in manufacturing of finished metal products has been growing since the recent years. Great influence is on physical ergonomics that analyses work-related musculoskeletal disorders in various economics sectors as well as in industrial manufacturing. The manufacturing operations requires a many manual handling activities, awkward postures, lifting and moving big, heavy and inconvenient products [1]. It can result in very serious problems on worker's health [2]. Heavy manual work affects not only the system of muscles, skeleton and connective tissues, but also cardiovascular system. In scientific research it is pointed out that to ensure optimal physiological results in the work process it is necessary to choose such work tasks that do not cause threat to body physiology. Usually physiologic reaction of the body to heavy manual

work is general tiredness, more rarely – local muscular fatigue. The most commonly used physiological criterion for evaluation of the physical load is energy consumption during physical load and consumption of oxygen [3]. During such analysis usually the work content is divided into smaller tasks and physiological impact can be measured by the expenditure of the energy in these individual tasks [4]. In several researches the oxygen consumption is used to analyze the workload severity [3, 5] have developed regression equations to predict oxygen consumption using personal, task, and work-place variables.

In scientific research for comparative analysis of objective measurements Rating of Perceived Exertion (RPE) scale is used, worked out by Swedish scientist *Gunnar Borg* in 1982. This instrument is used for evaluation of effort and fatigue of the individual, for instance, during intensive physical work. Work intensity, in its turn, determines the load of individual functional systems (muscular, skeleton and connective tissues, cardiovascular, etc.) during the work process. It is a subjective opinion on physical feelings (heart function, breathing frequency, increased sweating, blood pressure changes, muscular fatigue, etc.) in the work process.

The research was to perform physical workload analysis in metal processing industry operations (assembly operators, packaging operators and inspection staff) using objective ergonomics research methods. The study was carried out in a medium sized metal manufacturing enterprise in Latvia in the department of manufacturing of ironing boards. The study was approved by the Human Ethics and Institutional Review Board at the University of Latvia in 2018.

2 Materials and Methods

2.1 Research Design

30 assembly operators, 30 packaging operators and 15 members of the inspection staff with chronic pain (for four months or more) in the neck, shoulders, arms, hands and legs agreed to take part in the objective (heart rate monitoring, muscle myotonometry) measurements. The inclusion criteria were: age, length of service, presence of chronic pain in certain body parts, incl. neck and shoulder area, the back, arms and legs (medical examination data); full consent to participate in the research, no physical activities (exercises during the work breaks and after the work). The exclusion criteria were: acute pain in shoulders and neck area, arms, legs and back; non-work related disorders, and having not mandatory medical examinations. The investigation endured for one year period. Demographic information of the assembly, packaging and inspection operators are shown in Table 1.

2.2 Research Methods

A questionnaire was used to find out the opinion of employees on existing physical workload in the department of ironing board manufacturing. Seventy-five employees were included in the survey.

Table 1. Demographic factors of the assembly, packaging and inspection operators, including length of service, mean age and range, mean height, mean weight, mean body mass index (BMI), mean rest heart rate (RHR) and standard deviation (SD)

Population (length of service)	n	Mean age $\pm$ SD	Range	Mean height, cm $\pm$ SD	Mean weight, kg $\pm$ SD	Mean BMI, kg/m ² $\pm$ SD	Mean RHR, beats/min $\pm$ SD
Assembly operators	30	47.8 $\pm$ 13.6	22–72	172.6 $\pm$ 8.0	79.9 $\pm$ 7.5	27.0 $\pm$ 3.7	76.5 $\pm$ 7.3
0–7 years	10	36.9 $\pm$ 14.9	22–59	168.9 $\pm$ 7.3	83.0 $\pm$ 8.9	29.2 $\pm$ 3.3	58.7 $\pm$ 9.6
8–15 years	15	51.3 $\pm$ 7.8	34–67	174.3 $\pm$ 8.6	79.4 $\pm$ 6.7	26.4 $\pm$ 3.8	72.3 $\pm$ 8.2
>15 years	5	59.0 $\pm$ 11.1	49–72	175.4 $\pm$ 5.6	75.4 $\pm$ 5.0	24.5 $\pm$ 1.9	77.0 $\pm$ 8.6
Packaging operators	30	41.2 $\pm$ 19.2	22–65	167.5 $\pm$ 18.7	71.4 $\pm$ 10.2	26.4 $\pm$ 4.1	71.7 $\pm$ 7.6
0–7 years	12	27.8 $\pm$ 6.6	22–40	170.6 $\pm$ 14.8	69.5 $\pm$ 9.8	25.8 $\pm$ 3.3	55.7 $\pm$ 8.8
8–15 years	10	30.6 $\pm$ 6.4	30–48	168.6 $\pm$ 12.4	71.5 $\pm$ 9.7	26.7 $\pm$ 3.7	60.3 $\pm$ 8.7
>15 years	8	56.9 $\pm$ 7.6	42–65	166.6 $\pm$ 11.9	73.5 $\pm$ 11.3	27.2 $\pm$ 3.8	63.8 $\pm$ 7.8
Inspection staff	15	48.6 $\pm$ 11.8	38–70	172.8 $\pm$ 5.3	76.3 $\pm$ 8.7	25.6 $\pm$ 2.8	57.3 $\pm$ 4.2
0–7 years	7	47.6 $\pm$ 11.3	38–66	172.9 $\pm$ 5.4	75.3 $\pm$ 8.6	25.2 $\pm$ 3.2	74.2 $\pm$ 7.5
8–15 years	8	49.6 $\pm$ 13.0	34–70	172.8 $\pm$ 5.6	77.1 $\pm$ 9.4	25.8 $\pm$ 2.7	63.1 $\pm$ 6.8
>15 years	0						

In order to analyze work strain and work heaviness category (WHC) the Borg Scale of Ratings of Perceived Exertion (RPE) was used [6] with the scale from 6 to 20, where 6 means - no intensity (strain) at all, and 20 is maximum intensity. The RPE measurements were carried out in the work process.

Heart Rate Monitoring (HRM) was used to determine physical workload by setting the work heaviness degree [7]. To measure the heart rate the device POLAR S810iTM and data processing software Polar Precision Performance was used which allowed to transform HR data into metabolic energy consumption (kcal/min) [8]. NIOSH (USA) standard ISO 28996 energy expenditure classification was used to express the work heaviness degree (see Table 2).

Table 2. Work heaviness classification in terms of energy expenditure

Workload categories		Energy expenditure	
NIOSH (USA) standard ISO 28996 [9]		Male, kcal/min	Female, kcal/min
Light work	I	2.0–4.9	1.5–3.4
Moderate work	II	5.0–7.4	3.5–5.4
Hard work	III	7.5–9.9	5.5–7.4
Very hard work	IV	10.0–12.4	7.5–9.4
Ultimate work	V	more 12.5	more 9.5

MYOTON-3 device was used in order to carry out analysis of muscle's functional state and fatigue levels [10]. Myotonometry with Myoton-3 device allows to measure viscoelastic parameters of various muscles groups and provide functionality analysis for diagnostics [11]. Measurements were carried out with relaxed muscles before the beginning of the work cycle during one week cycle for such muscles: *m. extensor digitorum*; *m. flexor carpi radialis*; *m. gastrocnemius (caput mediale)*; *m. tibialis anterior* and *m. trapezius (upper part)*. All involved persons were in a similar sitting position during the measurements.

Statistical analysis with descriptive statistics was provided with computer software SPSS.20.0 [12]. The reliability was calculated with the confidence interval (95% CI) [13] and reliability interval was determined using Cohen's Kappa (κ) coefficient [14].

3 Results and Discussion

The study involved metal manufacturing organization with the department of metal boards. This department employed 75 workers, males only. All of them participated in the survey.

Survey results revealed that 36.7% of assembly operators complained generally of having pain in their neck region, 42.5% - in the shoulders, 22.6% - in the palm and 11.7% - in the lower back. It has to be noted that the most complaints regarding the pain in the mentioned bodily parts were uttered by assembly operators aged 34–67 with the length of service 8–15 years (CI = 1.56–2.62): 52.3% - the neck region, 51.0% - the shoulders, 33.2% - the palm and 20.0% - the lower back. Packing operators noted the pain after work as follows: 55% - in the neck region, 70% - in the upper back, 48% - in the arms and lower legs. The greatest discomfort is felt by employees who have been working in the profession for 8–15 years and more, which is the same as aforementioned data (CI = 0.53–5.70). Of the inspection staff, 78% with the length of service from 8 to 15 years marked in the survey that during the work they feel discomfort in the upper back and more in the arms and legs (CI = 0.54–4.97). The survey data showed that all participants noted exposure to high physical overload at work: they lift and move ironing boards with weight of 10–15 kg, but packaging operators marked that sometimes they lift and move up to 25 kg. The hands, legs and lower back are the most stressed body parts in the work process. Applying the Borg Scale to determine physical load intensity it was found out that assemblers of ironing boards and packers of ironing boards recognized that their work corresponds to heavy work category (15–16 points), but inspection staff—somewhat heavy (13–14 points).

Data shows that almost all metal boards' workers (87%) have forced and awkward work postures. Mainly assembly and packing operators aged 18 to 35 years indicates that work is not intensive. It should be noted that 78% of younger employees aged 22–35 smoke during rest breaks and after work, they also often use alcohol. Physical activities in their leisure time are done by 34% only.

HRM was performed for 6 h long work process including rest breaks. Research results of heart rate monitoring for assembly operators, packing operators, and inspection staff are shown up in Table 3.