The Influence of Body Posture on Muscle Fatigue and Reaction Time during Truck Driving

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Abstract— **Longlasting truck driving leads often to excessive muscle load and muscle fatigue. Body postures maintained during long time by drivers may cause not only a disturbances of physiological functions but also fatigue of musculoskeletal system and may lead to rise the musculoskeletal disorders. Excessive muscle fatigue as well as the musculoskeletal disorders may have an influence on the risk of the car accidents. One of the commonly used methods to assess the load and fatigue from the muscles is a surface electromyography (EMG). A great number of studies indicate the relationship between the EMG signal amplitude and the force developed by muscles. Moreover, many studies confirm the effect of the muscle load on the values of the parameters characterising the EMG signal power spectrum and indicating muscle fatigue.**

The aim of the study was to evaluate the influence of the body posture maintained during truck driving on muscle load and fatigue as well as reaction time among truck drivers.

The studies with usage of surface electromyography among 10 men in age between 20 and 23 years were carried out. The EMG signal from four muscles of the right lower limb (*medial gastrocnemius*, *lateral gastrocnemius*, *rectus femoris* and *vastus lateralis*) was registered. For every participant six tests were carried out. The tests differed in the angles in the hip joint and knee joint. Every test took five minutes. The participants were steering by the right lower limb on the research stand imitating real truck driver work stand. During tests the reaction time on unexpected events was also registered.

The results of the analysis indicate, that body posture maintained during truck driving influences the EMG signal parameters, commonly used as a muscle load and muscle fatigue indicators. The results of the study can serve as guidelines to truck drivers regarding body posture during truck driving.

Keywords— **EMG, muscle fatigue, truck driving, reaction time.**

I. Introduction

Longlasting truck driving leads often to excessive muscle load and muscle fatigue. Body postures maintained during long time by drivers may cause not only disturbances of physiological functions but also fatigue of musculoskeletal system and may lead to rise the musculoskeletal disorders, which have an influence on the risk of the car accidents.

One of the commonly used methods to assess the load and fatigue of the muscles is surface electromyography (EMG), which consists in registering the electrical signal with the usage of surface electrodes [1]. In order to estimate the muscle load during performing various activities the analysis of the EMG signal amplitude is carried out [2, 3]. Not only muscle strength, but also muscle fatigue affects the values of the EMG signal amplitude [4, 5]. The muscle fatigue can be observed in the EMG signal record, in the values of parameters such as amplitude (*RMS*), the mean power frequency (*MPF*) and the median frequency (*MF*).

Studies on the optimal body posture maintained during truck driving have been investigated for a long time [6, 7]. Moreover, scientists search for methods of assessing comfort while driving. Kolich i Tabun [8] reported that surface electromyography (EMG) is a good tool to evaluate the driver's comfort at workplace. Authors suggest that there is a relationship between the subjectively perceived level of comfort and the level of back muscles activation measured using surface electromyography. Fatollahzadeh [9] developed a mathematical model for choosing the comfortable body posture of professional drivers, depending on the anthropometric dimensions and the layout of controls in the cab.

Moreover, global studies concerned with determination of the effect of exhaustion on the safety of driving [10] and estimation of fatigue based on reaction time [11]. According to studies Ting *et al.* [12] and Al-Darrab *et al.* [13], increasing driving time at simulated truck driver work stand causes increase in the degree of sleepiness, reaction time, volatility of driving, which is associated with higher risk of car accident. However, there is a lack of the studies that indicate the influence of the drivers' body posture on muscle fatigue and reaction time.

The aim of the study was to evaluate the influence of the body posture maintained during truck driving on muscle load and fatigue as well as reaction time among truck drivers.

II. Methods

The studies among 10 men were carried out. The participants did not practice sports professional and did not have musculoskeletal disorders. Average (standard deviation) age, body weight and body height of participants are,

C.T. Lim and J.C.H. Goh (Eds.): WCB 2010, IFMBE Proceedings 31, pp. 119–122, 2010.
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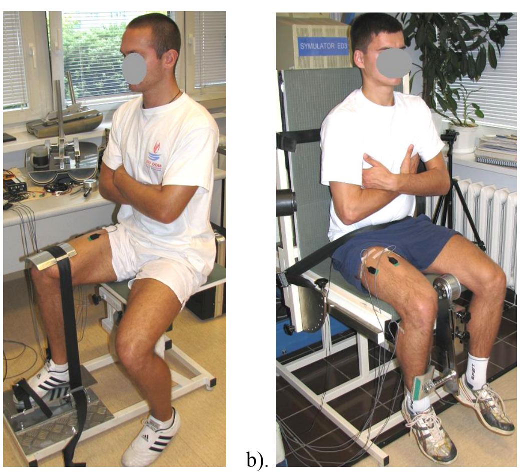
respectively: 21.8 years (0.6 years), 76.5 kg (5.1 kg), 182.1 cm (2.1 cm).

The EMG signal from four muscles of the right lower limb (*medial gastrocnemius -MG*, *lateral gastrocnemius -LG*, *rectus femoris -RF* and *vastus lateralis -VL*) was registered.

During tests the EMG signal, reaction time and torque from right lower limb were registered. In order to synchronize afterwards the EMG signal and reaction time measurements in time, as well as determine reaction time in different configurations of the lower limb, video recording with frequency of 60 frames/second was applied.

Device Bagnoli-16 (Delsys, USA) was used for measurement and analysis of the EMG signal. Bagnoli-16 combined with a computer enables observation and registering of the raw signal. Signal sampling frequency is 4 kHz. Bandwidth of Bagnoli-16 is 20-450 Hz. The EMG signal was recorded with surface electrodes. Before the electrodes were stuck, the skin had been cleaned and disinfected in spirit.

The first stage of measurements was to determine the maximum torque and registering of the EMG signal during maximal contraction of muscle. The research stand to measure torque in ankle joint (SPSS) was used to activate the *gastrocnemius* muscle. To activate muscles: *rectus femoris* and *vastus lateralis* the stand to measure torque of knee joint (SPK1) was used. Stand SPSS as well as SPK1 are presented in Figure 1.



a). b).

Fig. 1 Measurement of the maximum torque and the EMG signal during maximal contraction of muscle: a) *gastrocnemius* muscle (SPSS stand); b) *rectus femoris* and *vastus lateralis* muscles (SPK1 stand)

After the measurements at maximum load of tested muscles were done, the tests consists in steering by the lower limb on stand PR1 imitating real truck driver work stand (Fig. 2) were carried out. During the tests the EMG signal from the lower limb muscles was recorded. The task of participants was to pressure the lower limb on the pedal. During the test the pedal as well as the whole research stand was immovable, which enabled to carry out the measurements in isometric conditions. The value of force in the pedal was visible on the screen as a shift of the cursor, so participants could steer the pedal with the known strength. On the screen the curve was displayed. The task of participants was to steer the pedal in such a way to make the distance between the curve and the position of cursor minimal, so the cursor should be as close to the curve as possible. The measurement range of force for lower limb was 15-150N, which means that in the lowest position of the curve the tested person pushed with the force of 15N and in the highest position – with the force of 150N.

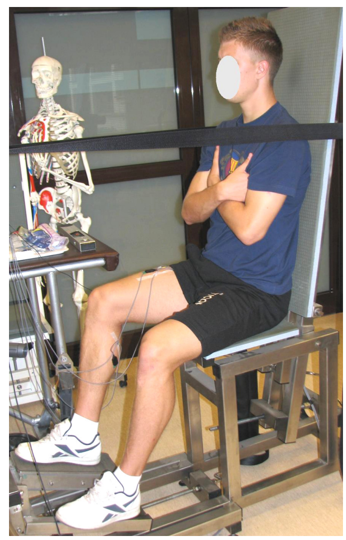


Fig. 2 The measurement on the research stand PR1

In certain, unknown for participants moments, the impulse in the form of the red circle imitating unexpected situation on the road appeared on the screen. Participants were supposed to press rapidly the pedal at the moment they noticed the impulse. The screen displaying the position of cursor and the impulse imitating unexpected situation on the road was recorded with the frequency of 60 frames per second, which allowed subsequent analysis of reaction time, i.e. the time between the appearance of the impulse and the sudden change in position of the cursor with time resolution of 0.01(6) sec.

Duration time of each test was five minutes. For each participant six tests were carried out. The tests differed in the angles in the hip joint and knee joint, which is shown in Table 1.

Table 1 Configurations of the knee, hip and ankle joint in six tests included in the experimental studies

The angle in the hip joint [°]	The angle in the knee joint [°]	The angle in the ankle joint [°]	Name of the test
90	90	90	90x90
90	110	90	90x110
90	130	90	90x130
110	90	90	110x90
110	110	90	110x110
110	130	90	110x130

In each of the tested postures the thigh was oriented horizontally. For the determination of the angles in the hip, knee and ankle joint an electronic protractor Bosch DWM 40L was used. The order of various tests was different and determined on the basis of random numbers tables.

Reaction time (*T*) and three EMG signal parameters (*RMS* - root mean square, *MF* - median frequency and *MPF* - mean power frequency), obtained by experimental tests in the six body postures were analysed.

At the beginning, in the middle and at the end of each of five-minutes tests the curve was at the constant level for 5 seconds, which enforced to keep the load in these intervals not only at static posture, but also at a constant level of muscle force. The parameters determined from the EMG signal recorded during tests with the load at a constant level enable to assess muscle fatigue generated during the tests.

The analyzed EMG signal parameters from the initial part of the measurement were labeled *RMS1*, *MPF1* and *MF1*, the parameters of the part corresponding to half the duration time of the test were marked as *RMS2*, *MPF2* and *MF2*, while the parameters set in the third, final part were named *RMS3*, *MPF3* and *MF3*. The EMG signal parameters corresponding to three parts of time in the six body postures were determined for all four analysed muscles (*MG, LG, RF* and *VL*).

The EMG signal parameters and the parameter *T*, determined in six body configurations allowed to analyse the influence of body posture on the fatigue of the musculoskeletal system and reaction time during driving.

III. Results

Figure 3 shows mean values and standard deviations of reaction time *T* in six body configurations.

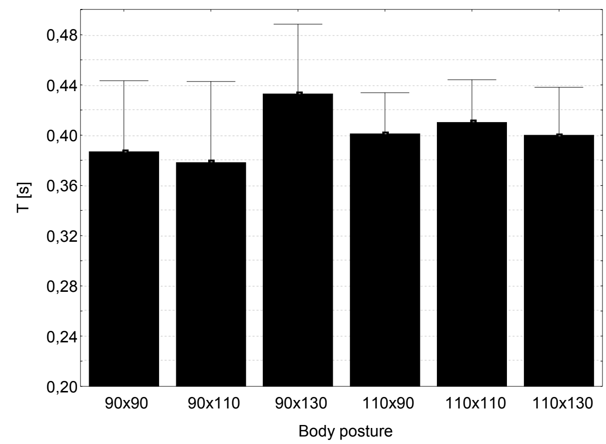


Fig. 3 The mean values and standard deviations of reaction time *T* in six body configurations

Based on the values of reaction time shown in Figure 3 it can be stated that the longest reaction time, with the value of 0.4329 s, was recorded in the body configuration 90x130, i.e. the body posture in which the hip angle is 90°, and the angle in the knee is 130°. The shortest reaction time, equal to 0.3782 s, was obtained in the body posture with the angle of 90° in the hip joint and the angle in the knee of 110° (configuration 90x110).

Taking into account tested muscles and three fragments of recordings for the six analyzed body postures, the index *W*, which expresses the aggregated fatigue of the musculoskeletal system was determined. To elaborate the index *W*, it was assumed, that changes in the EMG signal due to muscle fatigue, are reflected by the increase of *RMS* amplitude and the decrease of power spectrum parameters of EMG (*MF* and *MPF*). The index *W* was determined in accordance with the equation 1:

$$W = \sum_i \left[\left(Z_{RMS2} + Z_{RMS3} \right) - \left(Z_{MPF2} + Z_{MPF3} \right) - \left(Z_{MF2} + Z_{MF3} \right) \right] \quad (1)$$

where:

$Z_{n\,k}$ – change in the value of parameter *n* in the part *k* of the test compared to the initial part of the test,
$i = [MG, LG, RF, VL]$ – muscles included in the study.

The index *W* increases its value in case of the increase of *RMS* amplitude and the decrease of parameters *MPF* and *MF* in 2nd and 3rd part of the test in relation to the initial part of the test, taking into account all four tested muscles. The values of index *W* determined for all six studied body configurations are shown in Figure 4.

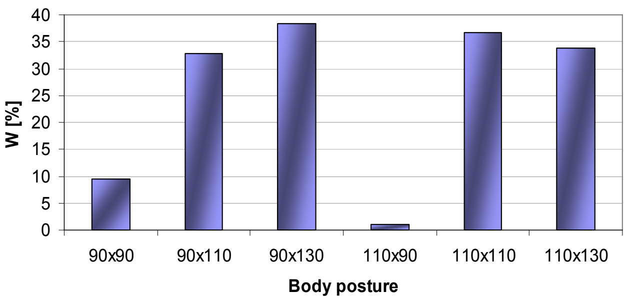


Fig. 4 Values of the index *W* set on the basis of changes in the EMG signal parameters (*RMS*, *MPF* and *MF*), calculated in the middle of the test and at the end of the test in relation to the values measured at the beginning of the test for all four analyzed muscles (*MG, LG, RF* and *VL*)

IV. Discussion

The analysis of research results, taking into consideration the reaction time to unexpected situation (parameter *T*, Figure 3) and the index *W* (Fig. 4) shows that the body posture that causes the greatest muscle fatigue of the lower limb and indicates the greatest reaction time of drivers' lower limb is the position in which the angle in the hip joint is 90° and the angle in the knee joint 130° (configuration 90x130). Configuration of the body resulting in the smallest muscle fatigue of the lower limb is 110x90, which is the position with the angle in the hip joint of 110° and in the knee joint of 90°. However, in terms of reaction time, the configuration 90x110 is optimal (angle in the hip joint 90°, angle in the knee joint 110°).

The results of the study allowed to determine the effect of body position on the muscle fatigue and the reaction time during truck driving.

V. Conclusions

The obtained results will allow to increase the drivers' awareness of heavy transport, which can reduce the risk of occurring disorders of the musculoskeletal system and may also improve the safety from the perspective of the professional drivers as well as other road users.

Acknowledgment

This paper has been prepared on the basis of the results of a project carried out under the National Programme "Improvement of Safety and Working Conditions", Phase I – 2008-2010, supported by the Ministry of Labour and Social Policy. The Central Institute for Labour Protection - National Research Institute has been the co-ordinator and the main performer of the Programme.

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