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ORIGINAL RESEARCH PAPER

Design and fabrication of portable motion recorder: comparing lumbar kinematics in workers with and without low back pain in assembly line of a car manufacturing industry

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ABSTRACT

Introduction: Workers in car manufacturing industry are at risk of a high prevalence of musculoskeletal disorders, especially low back pain. Therefore, in the present study aimed to design and fabricate a portable device to evaluate the low back kinematics and to compare these variables in workers with and without low back pain (LBP) in assembly lines of an automotive industry.

Material and Methods: In the present research workers postures were assessed using OWAS direct observational method. Moreover, simultaneously, prevalence and intensity of low back pain were evaluated by Dutch Musculoskeletal Questionnaire (DMQ) and Visual Analogue Scale (VAS). After fabricating motion analysis device, a field study was conducted using the designed device among 16 volunteers to investigate low back kinematic variables in two groups of workers: LBP and non-LBP.

Results: The results showed that 62.1 percent of all working postures were high risk with corrective action levels of 3 and 4. On average, 86.1 percent of workers experienced LBP in the previous 12 months. Regarding comparison of kinematic variable in the two groups of LBP and non-LBP, workers without LBP had higher degree and duration (in second) of movements (forward flexion, lateral bending, extension, and twisting), as compared to those with LBP. However, only movement range of forward flexion in non-LBP group (mean: 64.29 and SD: 8.41), was significantly higher than those with LBP (mean: 58.97 and SD: 11.34).

Conclusion: The device can be used as an effective tool in the ergonomics studies in the field of back pain, due to its potential to record the kinematics of the trunk, as well as its lightweight and non-interference with the task. Device's validity was acceptable based on the comparison of the results of this device with those obtained from inclinometer.

Keywords: *low back pain, Kinematics, motion analysis device, car manufacturing industry*

1. INTRODUCTION

Body posture is one of the factors affecting spinal compression/shear forces and moments. Specifically, the lumbar posture and movements, during industrial tasks are important parameters that determines the internal load distributions, and can increase the risk of lumbar dysfunction (1, 2). A review study by Nelson and Hughes (2010) found that prolonged lumbar flexion can increase the risk of lumbar disc injury and consequently the risk of low back pain (3). Shin and D'Souza (2010) investigated the effect of repetitive back movements (flexion and extension) on low back pain using electromyogrphic signals and they showed a direct relationship between repetitive flexion and extension movements and muscle activity changes in the lumbar muscles recorded by

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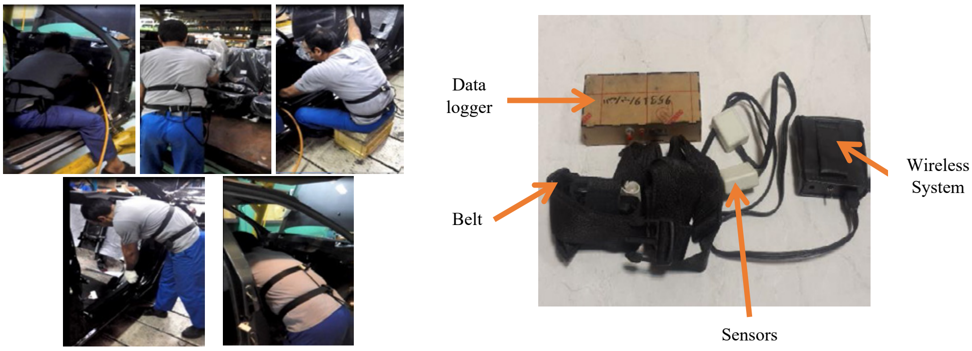

Fig. 1. The designed lumbar motion capture system in the present study

the electromyography device (4). Survey of lumbar movements provides the possibility for accurate prediction of the onset and severity of lumbar injuries (5). Therefore, there is a need for methods and tools to assess back movements in order to prevent low back pain and injuries. The currently available evaluations tools can be categorized into questionnaire-based, observation-based, and objective methods.

The questionnaires and observational tools have been widely used in a wide range of studies so far. Minimal interference with the workers tasks and the low cost are of the benefits of these assessments tools. However, the results are vastly dependent on the subjects' evaluations or experience of the examiner. Another limitation, which limits the generalizability of the results, is the inability for continuous evaluations of tasks (6, 7).

Considering the role of back movements (number of movements and their duration) in development of low back pain and disabilities as well as the need for objective and continuous evaluations of these parameters, the purpose of this study was to (1) design and fabricate a device to evaluate the kinematic variables of the trunk and to (2) study the effect of these variables on low back pain among employees of one of the car manufacturing industries. Workers in car manufacturing industry are at risk of a high prevalence of musculoskeletal disorders, especially low back pain, due to direct exposure to a wide range of ergonomics issues (8).

2. MATERIAL AND METHODS

In the present research, following task analysis by TTA technique, workers postures were assessed using OWAS direct observational method (9, 10) in order to identify high-risk workstations. Moreover, simultaneously, prevalence and intensity of low back pain were evaluated by Dutch Musculoskeletal Questionnaire (DMQ) (11) and Visual Analogue Scale (VAS) (12). After designing and constructing the motion analysis device, a field study was conducted using the designed device among 16 volunteers to investigate low back kinematic variables in two groups of workers: LBP (n=10) and non-LBP (n=6). The designed device consisted of an accelerometer, a magnetometer, and a gyroscope with sampling frequency of 30 Hz.

In order to test the accuracy of the developed device, it was attached to the movable arm of an electronic goniometer (Sammons Preston, Rolyan, USA). By adjusting the movable arm of the goniometer to the desired angle, the angle measured by the developed device was recorded. In the sagittal plane, angles from zero to 130 degrees with an interval of 5 degrees were recorded three times. Similarly, for the frontal plane, angles from zero to 50 degrees were recorded by 5-degree intervals three times. Using Spearman correlation coefficient, the correlation between the results of the goniometer and the developed device was obtained (r=0.7 to 0.85).

3. Results and Discussion

The results of analysis by OWAS method showed that 62.1 percent of all working postures were high risk with corrective action levels of 3 and 4. On average, 86.1 percent of workers experienced LBP in the previous 12 months. Furthermore, mean (SD) of pain intensity (ranged between 0-100) was obtained 57.95 (15.46).

According to the findings, non-LBP group had higher job tenure than those with LBP (P-value=0.024). Considering the participants' anthropometric characteristics, the height of LBP group was significantly higher than the height of non-LBP people (P-value=0.04).

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Table 1. Comparison of low back movements' magnitude (degree) in LBP and non-LBP workers using Mann-Whitney statistical test

Movement	Group	Mean	SD	Minimum	maximum	P-value
Forward flexion	LBP	58.97	11.34	48	75.78	0.05*
	Non-LBP	64.29	8.41	54.20	76.33	
Lateral bending	LBP	10.4	3.20	7	14	0.63
	Non-LBP	11.58	0.56	3.50	13.50	
Extension	LBP	4.73	0.56	3.50	5	0.71
	Non-LBP	6.55	2.41	5	10	
Twisting	LBP	14.4	1.34	12	15	0.54
	Non-LBP	17.20	2.16	15	20	

Table 2. Comparison of low back movements' duration (second) in LBP and non-LBP workers using Mann-Whitney statistical test

Movement	Group	Mean	SD	Minimum	maximum	P-value
Forward flexion	LBP	22.94	17.04	4.7	7.84	1.00
	Non-LBP	24.7	17.7	5.5	8.6	
Lateral bending	LBP	1.39	0.78	0.3	0.67	0.63
	Non-LBP	1.8	1.1	0.5	1.1	
Extension	LBP	2.9	1	0.8	1.3	0.59
	Non-LBP	3.5	2.2	1.5	1.9	
Twisting	LBP	2.7	1.8	0.7	0.99	1.00
	Non-LBP	2.7	1.3	1.2	0.9	

A significant negative correlation between low back pain intensity and work experience (P-value=0.013 and r=-0.253) was found using Pearson correlation coefficient. In other word, pain intensity decreases with increase in work experience. However, the correlation between age and pain intensity was not statistically significant (P-value= 0.290 and r = -0.11).

Comparison of different back movements in low back pain and non-low back pain participants was done using Mann-Whitney test (Table 1). The results showed that the mean forward flexion angle in LBP and non-LBP groups was significantly different; so that non-LBP group had greater trunk flexion (Table 1). Moreover, the average duration of maintaining the posture for all trunk movements was higher in non-low back pain workers as compared to those with low back pain. In addition, the mean duration of forward flexion in both groups was longer than other movements (lateral bending, extension, and twisting). In the study by Sheeran et al. (2019), the spinal movements of people with low back pain and non-low back pain were measured using an IMU sensor. Similar to the present study, subjects with low back pain had significantly less range of motion (ROM) in the lumbar region during forward flexion than non-back pain subjects (13).

Regarding the number of movements performed by worker with low back pain and non-low back pain, the mode (maximum frequency) of forward bending among participants with low back pain and non-low back pain is 6 and 5, respectively.

4. Conclusions

Overall, in the present study, it was observed that kinematic variables including trunk forward flexion, lateral bending, extension, twisting (in degree), as well as the duration of maintaining these postures (in seconds) are greater in non-LBP group as compared to those with LBP. However, these differences were statistically significant only for forward flexion angle.

The designed motion analysis device could

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efficiently differentiate LPB and non-LBP groups. Considering the capability of this device to record workers trunk kinematics, as well as its light weight and non-interference of the device with their tasks, it can be used in ergonomics assessments in the field of low back pain. Moreover, comparing the results of the designed device with those of an inclinometer confirmed its accuracy.

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