Thai Journal of Ergonomics: Volume 2 Issue 1 January – June 2019: p. 30-41
วารสารการยศาสตร์ไทย: ปีที่ 2 ฉบับที่ 1 มกราคม-มิถุนายน 2562: หน้า 30-41

นิพนธ์ต้นฉบับ
(Original article)

ความผิดปกติของโครงสร้างส่วนบนและส่วนล่างของร่างกายในพนักงานคอมพิวเตอร์ และ พนักงานยก ในบริษัทน้ำมันและก๊าซ

Upper and lower crossed syndromes among computer and manual material handling workers in an oil and gas company

วรรธนะ ชลายนเดชะ[1*] คีรินท์ เมฆโหรา[1] ชุติมา ชลายนเดชะ[1] ไฮฟะห์ สาแม[2] และ เพชรรัตน์ ภูอนันตานนท์[1]
Wattana Jalayondeja[1*], Keerin Mekhora[1], Chutima Jalayndeja[1], Haifah Samae[2], and Petcharatana Bhuanantanondh[1]
[1]คณะกายภาพบำบัด มหาวิทยาลัยมหิดล
[1]Faculty of Physical therapy, Mahidol University (wattana.jal@mahidol.ac.th)
[2]สาขาวิชากายภาพบำบัด สำนักวิชาสหเวชศาสตร์ มหาวิทยาลัยวลัยลักษณ์
[2]Department of Physical Therapy, School of Allied Health Sciences, Walailak University
*Corresponding author

บทคัดย่อ: การใช้คอมพิวเตอร์และการยกขนเป็นปัจจัยเสี่ยงที่อาจทำให้เกิดโรคของกระดูกและกล้ามเนื้อ ได้แก่ อาการปวด การไม่สมดุลย์ของกล้ามเนื้อ และความตึงตัวของระบบประสาท การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อเปรียบเทียบ จุดเจ็บ ความไม่สมดุลย์ของกล้ามเนื้อ และความตึงตัวของระบบประสาทในผู้ใช้คอมพิวเตอร์ 42 คน และพนักงานยกขน 34 คน กลุ่มตัวอย่างไม่มีอาการแทรกซ้อนอื่นๆ เช่น โรคทางระบบหายใจและหลอดเลือด ภาวะผิดปกติของระบบประสาทและกล้ามเนื้อ ภาวะกระดูกหักและภาวะหลังผ่าตัด ข้อมูลทั่วไปของกลุ่มตัวอย่างและจุดเจ็บถูกบันทึกด้วยแบบสอบถาม มีการตรวจร่างกายเพื่อดูความยาวและความแข็งแรงของกล้ามเนื้อและความตึงตัวของระบบประสาท พบว่าพนักงานคอมพิวเตอร์มีอาการปวดคอและหลัง ความตึงตัวของกล้ามเนื้อเพคทอลาริสเมเจอร์ ความตึงตัวของเส้นประสาทมีเดียน และระบบประสาทแกนกลางมากกว่าพนักงานยกขน นอกจากนี้ยังพบว่าพนักงานคอมพิวเตอร์มีความแข็งแรงของกล้ามเนื้อแทรพพิเซียสส่วนกลาง กล้ามเนื้องอและหุบสะโพกที่น้อยกว่า การศึกษาครั้งนี้พบว่าพนักงานคอมพิวเตอร์มีความเสี่ยงที่จะเกิดอาการปวดหลังและคอ อาการอัปเปอร์ครอสซินโดรม และการตึงตัวของเส้นประสาทมากกว่าพนักงานยกขน

ABSTRACT: Computer use and manual material handling (MMH) are both occupational risk factors for musculoskeletal disorders. These include pain, muscle imbalance and tension in nervous system. The study aims to compare pain area, muscle imbalance and neural tension between both kinds of workers. Participants were 42 computer users and 34 MMH workers. They had no history of cardiorespiratory disorders, musculoskeletal or neuromuscular deficits, fracture and operation. Demographic data and body pain area were collected by a questionnaire. Physical examinations were muscle length, strength and neurodynamic tests. There are significant higher percentage of neck and upper back pain, tightness of pectoralis major muscle, positive results in upper limb neurodynamic test of median nerve and slump test, lower strength of middle trapezius, hip flexor and adductor muscles in computer users when compared to MMH workers. The current study suggests that computer users may be at risk of neck and upper back pain, upper cross syndrome, and neural tension.

คำสำคัญ: พนักงานคอมพิวเตอร์ การยกขน ความไม่สมดุลย์ของกล้ามเนื้อ ความตึงตัวของระบบประสาท โรคระบบกล้ามเนื้อและกระดูก
Keywords: Computer user, Manual material handling, Muscle imbalance, Neural tension, Musculoskeletal disorders

1. INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) have been concerned in industries worldwide [1-4]. WMSDs were the biggest cause of absence from work. Almost half of workers' compensation costs in all European member states were spent on WMSDs [5]. In Korea, cost of WMSDs increased from 105.3 billion won in 2004 to 163.3 billion won in 2007 [2]. These indicated that WMSDs are the leading cause of worker's disability and lead to high medical cost and financial stress.

WMSDs are cumulative occupational injuries involving tissue damage such as muscles, tendons, and nerves [1}, [6-8]. Causes of WMSDs are prolonged static postures, repetitive movements, awkward postures and overexertion [8, 9]. Computer users and manual material handling (MMH) workers have an occupational risk in common, that is WMSDs [9]. Computer users spend many hours with computers. They also assume prolonged static and awkward postures. MMH works can be categorized as lifting, lowering, pushing, pulling, and carrying objects by hands. Workers also assume in awkward postures. In addition, their jobs involve repetitive arm movements and overexertion [8, 10]. Both types of workers usually complain of neck, upper extremity and lower back pain [8-15].

Muscle and neural impairments can induce pain and body discomfort. Muscle imbalance also causes chronic muscle adaptation into tightness and weakness. Imbalance between tightness and weakness of anterior and posterior muscles of the body extremities were found in subjects with neck and back pain [16, 17]. An imbalance pattern of upper extremity muscles is called upper crossed syndrome which is common in individuals with neck pain. Upper crossed syndrome includes tightness of upper trapezius, levator scapulae, sternocleidomastoid, and pectoral muscles and weakness of deep cervical flexor, lower trapezius, and serratus anterior muscles. Lower crossed syndrome is an imbalance pattern of lower extremity muscles which can be characterized by tightness of back extensor, rectus femoris, and iliopsoas muscle and weakness of abdominal and gluteal muscles. This syndrome is a common form of muscle imbalance that can cause back pain [16, 17].

It was proved that nervous system has close relationship with musculoskeletal system. If muscles become tightness, nerve compression may occur [8]. Chronic nerve compression and restriction can increase neural tension by limitation of blood circulation induced by muscle tightness. This can induce inflammation of the nerve and lead to pain [7], [18, 19]. Neurodynamic tests, such as upper limb neurodynamic test (ULNT), slump and straight leg raise test (SLR), are commonly used in order to identify neural tension [19].

Up to now, there are no studies involving WMSDs, especially, upper and lower crossed syndrome related to type of work such as computer and MMH workers. Therefore, the objectives of this study was to determine the prevalence of musculoskeletal and neural impairments and to compare the parameters of impairments in terms of pain, muscle tightness, muscle strength and neural tension among these two types of workers. This information can lead to the development of further management of impairment..

2. MATERIALS AND METHODS

This study was conducted a cross-sectional research design among the workers in oil and gas company at the exploration site, Phisanulok province, Thailand. Data collection were self-reported questionnaires and physical examination that were done on May to June, 2015. This study was approved by the Mahidol University Central Institutional Review Board (MU-CIRB COA. No. 2015/046.1604).

2.1. Participants

Male participants who aged 20-60 years and had experienced of work at least one years were recruited from an oil company exploration site in Thailand. They were categorized into two types of workers: computer user (COM) and manual material handling (MMH) workers. COM is defined as those who worked in the office with computer used and document. MMH is defined as those who worked as lifting, lowering, pushing, pulling and carrying objects. Participants with cardiovascular or respiratory disorders, musculoskeletal deformities such as scoliosis or ankylosing spondylitis, neurological disorders such as muscles paralysis or neuromuscular dystrophy, history of fracture and operation involving neck, trunk, upper and lower extremity were excluded.

2.2 Self-reported questionnaire

A questionnaire was used for self-reporting the musculoskeletal pain area, demographics and work characteristics. The question of musculoskeletal pain was adapted from the standard Nordic questionnaire for identifying the body area of pain including neck, shoulder, wrist, upper back and lower back during the last 7 days [20]. Demographic data were collected age, weight, height, dominant hand, frequency of exercise per week and medical history. Work characteristics were recorded type of work, the amount of computer use (hour/day), the amount of time for sitting, standing or walking during work (hour/day), the repetitive arm movement (hour/day) and the weight of lifting object (kilograms).

2.3 Physical examination

2.3.1 Muscle length test

Ten postural muscles were measured their length at both right and left sides. Three including sternocleidomastoid, upper trapezius and levator scapulae muscles were measured in sitting position. The others including pectoralis major and minor, iliopsoas, rectus femoris, tensor facia latae-iliotibial band (TFL-ITB), hip adductor and hamstrings muscles were measured in lying position based on the standard procedures [16, 21]. Passive movement was used to measure muscle length test and performed by two physical therapists. The moderate to high of interrater reliability was obtained (Kappa's agreement 0.7 to 1.0). Muscle length test were reported as 'normal length' that referred to full range of motion with soft end feel and 'tightness' that referred to limit range of motion with firm/hard end feel [22].

2.3.2 Muscle strength test

Muscle strength was measured by a hand-held dynamometer with the manual muscle test technique [23-27]. Muscles were measured at neck (flexor and extensor groups), shoulder (elevator, depressor, protractor and retractor groups), and hip (flexor, extensor, abductor and adductor groups). Strength test was performed by two physical therapists. The moderate to high of interrater reliability was obtained (ICC (3,1) 0.68 to 0.96). Data were reported in percentage of body weight calculated from muscle strength (kilogram) and divided by each subject body weight (kilogram).

2.3.3 Neurodynamic test

Three neurodynamic tests was used for evaluating the length and mobility of neural system including upper limb neurodynamic test for median nerve (ULNT1), slump test and strength leg raise (SLR) test for sciatic nerve [28]. Neurodynamic test was performed by two physical therapists. The moderate to high of interrater reliability was obtained (Kappa's agreement 0.7 to 1.0). Data were categorized into 'positive response' referred to the unchanged symptom after adding sensitize or desensitize maneuvers and 'negative response' referred to the changed symptom after adding sensitize or desensitize maneuver.

2.4. Data Analysis

Data were analyzed by the SPSS® (version 22.0; Armonk, NY: IBM). The prevalence of musculoskeletal pain area was reported in the number and percentage (%) of total population in each type of work. Descriptive statistics were used to report for continuous variables (mean and standard deviation) and categorical variables (number and percentage). The association between type of work (COM vs. MMH) and the musculoskeletal pain area was analysed using the crosstabulation test. The odd ratio (OR) and 95% confident interval (95%CI) were calculated. Independent t-test and Chi-square test were used for comparison all parameters of impairment between COM and MMH. The level of significance was set at p-value<0.05.

3. RESULTS

Of 242 males in an oil and gas company, 140 were not allocated to COM and MMH workers. Of 107, 76 workers were identified into the COM (n=42) and MMH (n=34) groups based on their work characteristics. There were nonsignificant difference of age, weight, height and hand dominant between COM and MMH groups (p>0.05). For MMH group, 21 workers reported 4.3±2.6 hour of the duration for repetitive arm movement. Twenty-four MMH workers reported 18.6±14.5 kilograms of weight lifting.

The result demonstrated that significant difference of computer use, sitting and standing/walking between COM and MMH groups as shown in Table 1. The duration of sitting in COM group were higher than the MMH group. Whereas MMH group had significantly higher duration of standing/walking, repetitive arm movement and heavy lifting load. There was no significant difference of the frequency of exercise per week between the two groups.

The comparison of muscles length and strength, and neurodynamic test between computer users and MMH groups are shown in Table 2, 3 and 4. There was a significant association between muscle length and types of work only in pectoralis major muscle.

Table1: Demographics and work characteristic of computer (COM) and manual material handling (MMH) groups

Characteristics	COM (n=42)				MMH (n=34)				*p*-value
	n	%	mean	sd	n	%	mean	sd	
Age (yr.)	42	100	37.2	10.0	34	100	34.1	8.2	
Weight (kg.)	42	100	72.5	9.1	34	100	71.3	10.9	
Height (cm.)	42	100	172.4	5.1	34	100	167.7	13.3	
Rt. hand dominant	39	92.9			30	88.2			
Work (hr/d)									
computer use	42	100	6.3	1.9	14	41.2	2.5	2.1	<0.001**
sitting	29	69.0	5.4	3.2	23	67.6	3.3	1.8	0.025*
standing/walking	24	57.1	2.1	1.2	16	47.1	4.8	2.6	<0.001**
Exercises									
no exercise	7	16.7			6	17.6			0.383
1-3 time/month	7	16.7			11	32.4			
1-3 time/week	20	47.6			11	32.4			
>3 time/week	8	19.0			6	17.6			

* statistical significant at $p<0.05$

** statistical significant at $p<0.001$

Table2: Comparison of muscle length test between computer (COM) and manual material handling (MMH) groups

Muscles length	COM (n=42)				MMH (n=34)				*p*-value
	normal		tightness		normal		tightness		
	n	%	n	%	n	%	n	%	
Sternocleidomastoid	21	50.0	21	50.0	17	50.0	17	50.0	1.000
Upper trapezius	12	28.6	30	71.4	4	11.8	30	88.2	0.059
Levator scapulae	15	35.7	27	64.3	14	41.2	20	58.8	0.820
Pectoralis major	7	16.7	35	83.3	13	38.2	21	61.8	**0.025***
Pectoralis minor	21	50.0	21	50.0	19	55.9	15	44.1	0.751
Iliopsoas[a]	3	7.3	38	92.7	4	11.8	30	88.2	0.468
Rectus femoris[a]	20	48.8	2	51.2	21	61.8	13	38.2	0.352
TFL-ITB	12	28.6	30	71.4	6	17.6	28	82.4	0.317
Hip adductor	36	85.7	6	14.3	33	97.1	1	2.9	0.061
Hamstring	2	4.8	40	95.2	4	11.8	30	88.2	0.448

TFL-ITB; tensor facia latae-iliotibial band

[a] missing one participant in COM group

* statistical significant at $p<0.05$

Table 3: Comparison of muscles strength with body weight normalized value between computer (COM) and manual material handling (MMH) groups

Muscles group	Muscle strength with body weight normalization				*p*-value
	COM (n=42)		MMH (n=34)		
	mean	sd	mean	sd	
Neck					
Flexor	0.17	0.06	0.17	0.05	0.467
Extensor	0.20	0.05	0.19	0.04	0.738
Right shoulders					
Elevator	0.25	0.10	0.27	0.10	0.348
Middle trapezius	0.18	0.04	0.21	0.04	***0.010****
Lower trapezius	0.09	0.03	0.11	0.04	0.091
Serratus anterior	0.24	0.07	0.25	0.06	0.571
Left shoulders					
Elevator	0.24	0.08	0.26	0.09	0.207
Middle trapezius	0.18	0.05	0.22	0.05	***0.006****
Lower trapezius	0.09	0.03	0.10	0.03	0.102
Serratus anterior	0.25	0.07	0.26	0.06	0.640
Right hip					
Flexor	0.23	0.07	0.27	0.07	***0.012****
Extensor	0.26	0.08	0.28	0.07	0.250
Adductor	0.21	0.04	0.22	0.05	0.246
Abductor	0.23	0.06	0.24	0.05	0.480
Left hip					
Flexor	0.24	0.07	0.29	0.08	***0.011****
Extensor	0.25	0.09	0.28	0.07	0.178
Adductor	0.20	0.04	0.23	0.05	***0.024****
abductor	0.23	0.06	0.24	0.05	0.485

*Statistical significant at $p<0.05$

Table 4: Comparison of neurodynamic tests between computer (COM) and manual material handling (MMH) groups

Neurodynamic test	COM (n=42)				MMH (n=34)				*p*-value
	positive		negative		positive		negative		
	n	%	n	%	n	%	n	%	
ULNT1	29	69.1	13	30.9	14	41.2	20	58.8	***0.015****
Slump	16	38.1	26	61.9	3	8.8	31	91.2	***0.003****
SLR	20	47.6	22	52.4	11	32.4	23	67.6	0.178

* Statistical significant at $p<0.05$

Table 5: The association between body's pain area and type of work

Body area	COM (n=42)		MMH (n=34)		OR	95%CI	p-value
	n	%	n	%			
Neck							
pain	12	28.6	2	5.9	6.8	1.3, 30.9	***0.011****
no pain	30	71.4	32	94.1	1.00	-	
Shoulder							
pain	12	28.6	4	11.8	3.0	0.8, 10.4	0.074
no pain	30	71.4	30	88.2	1.00	-	
Wrist[a]							
pain	4	9.5	1	2.9	3.5	0.3, 32.6	0.493
no pain	38	90.5	33	97.1	1.00	-	
Upper back[a]							
pain	10	23.8	1	2.9	10.3	1.2, 85.3	***0.025****
no pain	32	76.2	33	97.1	1.00	-	
Lower back							
pain	11	26.2	7	20.6	1.3	0.4, 4.1	0.568
no pain	31		27		1.00	-	

COM; computer user, MMH; manual material handling

* Statistical significant at $p<0.05$

[a] data was analysed by the Yate's correction of Chi-square test

The computer group had higher percentage of pectoralis muscle tightness than that of the MMH group (83.33% vs. 61.76%). In muscle strength test, it was shown that the computer group had significant lower strength of middle trapezius, hip flexor and hip adductor muscle compared to that of the MMH group (p<0.05). Results of neurodynamic test showed that the computer group had significant higher percentages of positive ULNT1 test (69.05% vs. 41.18%) and slump test (38.10% vs. 8.82%) compared to those of the MMH groups (p<0.05).

There were significant association between neck pain and type of workers and also upper back pain and type of workers. The computer group had higher percentages of neck (28.6% vs. 5.9%) and upper back pain (23.8% vs. 2.9%) compared to those of the MMH group. The workers in COM group were more likely to have pain at neck (OR 6.8, 95%CI 1.3-30.9, p=0.011) and upper back (OR=10.3, 95%CI 1.32-30.9, p=0.025) than those in MMH group as shown in Table 5.

4. DISCUSSION

4.1. Working time and body pain area

Based on the questionnaire, computer users spent 6.26 hours/day with computer and 5.36 hours/day of sitting. MMH workers lifted objects with average weight of 18.62 kg, performed tasks with repetitive arm movement for 4.83 hours/day and spent 4.29 hours/day on standing and walking. The differences of working time and work characteristics suggested that computer work is a kind of prolonged static work posture whereas MMH work use muscle forces and stayed in dynamic work postures. Compared the pain area between both groups, the computer group had greater pain area than MMH workers especially in neck and upper back area. The odd ratios of neck and upper back pain in the computer group were 6 and 10 times greater than those of the MMH group, respectively. Previous studies reported pain area among computer users found that they commonly suffered from neck [29, 30], lower back [31] and upper back pain [32]. However, neck, shoulder [33-34] and low back pain were also found in MMH workers [35]. The results of this current study suggest that computer work which is prolonged static work can cause more pain compared to dynamic work of MMH workers. Prolonged static posture can increase pain by static contraction, restriction of blood flow and the decrease of flexibility. In contrast, dynamic work produces more movement and higher blood flow during relaxation phase. This can lead to the reduction of muscle waste product from contraction and the decrease of muscle flexibility [8]. Our current finding shows a new evident which suggests that computer workers may have a high risk of WMSDs, especially neck and upper back when compared to MMH workers.

4.2. Muscle imbalance

Computer users tend to have tightness and weakness of muscle more than MMH workers. However, the results of physical examination showed that only some muscles revealed statistical significant difference. There were associations between higher tightness of pectoralis major muscle and weakness of both sides of middle trapezius, hip flexor and left side of hip adductors muscles in the computer group. A previous study suggested that computer users commonly adopt their postures into forward head and round shoulder [36]. Round shoulder posture causes tightness of pectoral muscle and weakness of middle trapezius muscle [16, 22]. Based on the pattern of muscle imbalance, upper crossed syndrome shows tightness of upper trapezius, levator scapulae, sternocleidomastoid, and pectoralis muscles and weakness of deep cervical flexor, lower trapezius, and serratus anterior muscles [16, 17]. However, the current study did not show full pattern of upper crossed syndrome. Tightness of pectoralis major and weakness of middle trapezius muscles may be the early signs of upper crossed syndrome in computer users. The pattern of lower crossed syndrome [16] which is tightness of back extensor, rectus femoris, and iliopsoas muscles and weakness of abdominal and gluteal muscles were not found in both computer and MMH workers.

4.3. Neural tension

Computer users tend to have higher positive test of neurodynamic test especially ULNT1 and slump test than MMH workers. Computer users suffered from median nerve tension and impairment were supported by many previous studies. Byng reported that computer users had significantly higher median nerve tension than non-computer users [37]. Mekhora et al. [38] reported increase median nerve tension after using computer for 2 hours. Many tasks of computer activity such as repetitive typing with keyboard [37, 39, 40], dragging mouse [41] and sustained poor posture can compress median nerves [39]. Moreover, tightness of muscle such as pectoral muscle may associate with median nerve tension [42]. Although, the current study cannot identify the cause that lead to increase median nerve tension but we can suggest that computer users are at risk of median nerve tension. Slump test also can detect tension of tissue such as dura mater, ligament and nerve as whole the spine. In contrast, SLR can detect only neural tension of lumbar and peripheral nerves of lower extremity. The large difference of percentage of positive slump test without approximate positive test of SLR test suggests that computer users may have tissue impairment at upper spine level whereas MMH workers may not have. Because of static posture during computer work, Sanders stated that prolonged static posture leads to the increase of intramuscular pressure resulting from compression of blood vessel and neural tissue [8] which may lead to increase tension of spine. In addition, MMH workers work in dynamic fashion which can lead to the decrease of neural tension.

4.4 Pain area and physical examination

In this study, there seems to be a relationship between body's pain area and physical examination in computer group. However, because of small number of participant in pain group, we cannot evaluate the association between body's pain and physical examination. This should be identified in future studies.

There were many limitations of this current study. Firstly, participants in this study were not randomized from the worker population. We recruited workers from only one oil company. Using the results of this study to other groups has to be done with caution. Secondly, this study did not determine the specific work characteristics such as types of computer used (notebook, laptop, PC or tablet), types of chair used (adjustable height or with or without arm rests), and other activities except for lifting in MMH work. These work characteristics could lead to the impairment found in our study. Further investigations in these matters are needed. In addition, according to upper or lower crosses syndrome, it is nearly impossible to measure deep muscle strength such as deep cervical flexor muscles. Up to now, there is no method to differentiate between strength of superficial and deep neck muscles when testing neck muscle strength. Further developments of this kind of measurement are needed.

5. CONCLUSION

Computer users worked in prolonged static posture (prolonged computer use and sitting) whereas MMH workers used extremity muscle force and stayed in dynamic postures (over lifting load and prolong standing/ walking). The result of pain area showed computer users had significant higher percentages of neck and upper back pain than those of MMH workers. The investigation of muscle imbalance and neural tension revealed that computer users had higher frequency of tightness in pectoralis major muscles, weakness of both side of middle trapezius, hip flexor and left hip adductor. Higher frequency of positive test of ULNT1 and slump test were also found in the computer group. It is suggested that computer users may be at risk of muscle imbalance, neural tension and WMSDs.

ACKNOWLEDGEMENTS

We would like to thank all workers who participated in this study and all staff of medical and occupational health at the exploration site, Phisanulok province of PTT Exploration and

Production Public Company, Thailand, for providing the necessary information during the process of data collection. This work was supported by the PTT Exploration and Production Public Company Limited, Bangkok Thailand

REFERENCES

[1] Putz-Anderson V, Bernard BP, Burt SE, Cole LL, Fairfield-Estill C, Fine LJ, et al. Musculoskeletal disorders and workplace factors. National Institute for Occupational Safety and Health (NIOSH). 1997; 104.

[2] Buckle P, Devereux J. Work-related neck and upper llimb: Musculoskeletal disorders. European Agency for Safety and Health at Work. 1999.

[3] Cherry NM, Meyer JD, Chen Y, Holt DL, McDonald JC. The Reported Incidence of Work-related Musculoskeletal Disease in the UK: MOSS 1997-2000. Occup Med. 2001;51(7):450-55.

[4] Kim EA, Nakata M. Work-related musculoskeletal disorders in Korea and Japan: A comparative description. Ann Occup Environ Med. 2014;26:17.

[5] Pinder A, Yeomans L, van den Heuvel S, Blatter B, Verjans M, Muylaert K, et al .Work-related musculoskeletal disorders :Back to work report .European Agency for Safety and Health at Work. 2007.

[6] Armstrong T J, Buckle P, Fine LJ, Hagberg M, Jonsson B, Kilbom A, et al. A conceptual model for work-related neck and upper-limb musculoskeletal disorders. Scand J Work Environ Health. 1993;19(2):73-84.

[7] Barbe MF, Barr AE. Inflammation and the pathophysiology of work-related musculoskeletal disorders. Brain Behav Immun. 2006;20:423-29.

[8] Sanders MJ. Ergonomics and the management of musculoskeletal disorders. 2nd ed. St. Louis, Mo.: Butterworth-Heinemann. 2003.

[9] da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. Am J Ind Med. 2010;53:285-323.

[10] Nordin M, Andersson G, Pope M. Musculoskeletal disorders in the workplace :Principles and practice .2nd ed .Philadelphia :Mosby Elsevier. 2003 .

[11] Randall SB, George J. A guide to manual materials handling and back safety. Division of Occupational Safety and Health, North Carolina, Department of Labor. 1997.

[12] Wærsted M, Hanvold TN, Veiersted KB. Computer work and musculoskeletal disorders of the neck and upper extremity: a systematic review." *BMC Musculoskelet Disord. 2010;*11:79.

[13] Lindegård A, Wahlström J, Hagberg M, Vilhelmsson R, Toomingas S, Tornqvist EW. Perceived exertion, comfort and working technique in professional computer users and associations with the incidence of neck and upper extremity symptoms." *BMC Musculoskelet Disord. 2012;*13:38.

[14] Mayer J, Kraus T, Ochsmann E. Longitudinal evidence for the association between work-related physical exposures and neck and/or shoulder complaints :a systematic review. Int Arch Occup Environ Health. 2012;85:587-603.

[15] Punnett L, Wegman DH. Work-related Musculoskeletal Disorders: the Epidemiologic Evidence and the Debate. J Electromyogr Kinesiol. *2004;*14(1):13-23.

[16] Page P, Frank C, Lardner R. *Assessment and treatment of muscle imbalance: the Janda approach*. Champaign, IL: Human Kinetics. 2010.

[17] Key J, Clift A, Condie F, Harley C. A model of movement dysfunction provides a classification system guiding diagnosis and therapeutic care in spinal pain and related musculoskeletal syndromes: a paradigm shift—part 2. *J Body Mov Ther.* 2008;12:7-21.

[18] Butler DS. 1989. Adverse mechanical tension in the nervous system: a model for assessment and treatment. *Aust J Physiother. 1989;*35(4):227-38.

[19] Butler D, Gifford L. The concept of adverse mechanical tension in the nervous system part 1: testing for “dural tension”. *Physiotherapy.* 1989;75(11):622-29.

[20] Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms." *Appl Ergon. 1987;*18(3):233-7.

[21] Davis DC, Quinn RO, Whiteman CT, Williams JD, Young CR. Concurrent validity of four clinical tests used to measure hamstring flexibility. J Strength Cond Res. 2008;22(2):583-8.

[22] Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. *Muscles: testing and function with posture and pain*. 5th ed. Baltimore: Lippincott Williams & Wilkins. 2005.

[23] Kolber MJ, Cleland JA. Strength testing using hand-held dynamometry. *Phys Ther Rev* 2005; 10(2): 99-112.

[24] Conable KM, Rosner AL. A narrative review of manual muscle testing and implications for muscle testing research. J Chiropr Med. 2011;10(3):157-165.

[25] Van der Ploeg RJ, Fidler V, Oosterhuis HJ. Hand-held myometry: reference values. *J Neurol Neurosurg Psychiatry*. 1991;54(3):244-247.

[26] Katoh M, Yamasaki H. Comparison of reliability of isometric leg muscle strength measurements made using a hand-held dynamometer with and without a restraining belt. *J Phys Ther Sci*. 2009;21(1):37-42.

[27] Michener LA, Boardman ND, Pidcoe PE, Frith AM. Scapular muscle tests in subjects with shoulder pain and functional loss: reliability and construct validity. *Phys Ther*. 2005;85 (11):1128-38.

[28] Butler DS. *Mobilisation of the nervous system*. Melbourne: Churchill Livingstone. 1991.

[29] Sabeen F, Bashir MS, Hussain SI, Ehsan S. Prevalence of neck pain in computer users. *Ann King Edward Med Uni*. 2013;19(2): 137.

[30] Bernard B, Sauter S, Fine L, Petersen M, Hales T. Job Task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. *Scand J Work Environmen Health. 1994;*20 (6):417-26.

[31] Loghmani A, Golshiri P, Zamani A, Kheirmand M, Jafari N. Musculoskeletal symptoms and job satisfaction among office-workers: a cross-sectional study from Iran. *Acta Med Acad. 2013;* 42(1):46-54.

[32] Janwantanakul P, Pensri P, Jiamjarasrangsri V, Sinsongsook T. Prevalence of self-reported musculoskeletal symptoms among office workers. *Occup Med. 2008;*58(6):436-8.

[33] Mayer J, Thomas K, Ochsmann E. Longitudinal evidence for the association between work-related physical exposures and neck and/or shoulder complaints: a systematic review. Int Arch Occup Environ Health. 2012; 85(6):587-603.

[34] Kim MH, Yoo WG. Effect of a worktable position on head and shoulder posture and shoulder muscles in manual material handling. *Work*. 2015;51(2):289-92.

[35] Klein BP, Jensen RC, Sanderson LM. Assessment of workers' compensation claims for back strains/sprains. J Occup Med. 1984;26(6):443-8.

[36] Szeto GP, Straker L, Raine S. A Field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Appl Ergon. 2002;*3 (1):75-84.

[37] Byng J. Overuse syndromes of the upper limb and the upper limb tension test: a comparison between patients, asymptomatic keyboard workers and asymptomatic non-keyboard workers. *Man Ther*. 1997;2(3):157-64.

[38] Mekhora K, Septham C, Jalayondeja W. Effects of Thai dancing on median neurodynamic response during 4-hour computer use.*J Med Assoc Thai.* 2015;98(5):S86-91.

[39] Tittiranonda P, Burastero S, Rempel D. Risk factors for musculoskeletal disorders among computer users. *Occup Med. 1999;*14(1):17-38.

[40] Novak CB, Mackinnon SE. Repetitive use and static postures: a source of nerve compression and pain." *J Hand Ther*. 1997;10(2):151-9.

[41] Keir PJ, Bach JM, Rempel D. Effects of computer mouse design and task on carpal tunnel pressure. *Ergonomics*. 1999;42(10):1350-60.

[42] Suwanasri C, Chongrattanameteekul N, Saenarat W, Potiyan J. Changing of nerve tension after releasing pectoral muscle in positive ULNT1 participants. *J Med Tech Phys Ther. 2013;* 25(3):297-310.

.