BRIEF and PLIBEL methods to evaluate musculoskeletal disorders of maintenance personnel

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Abstract*—*Purpose **Investigate work-related musculoskeletal disorders sites and related ergonomic factors among civil aviation maintenance men.** ***Methods*** **BRIEF and PLIEF methods were used for investigation and observation the posture, force, duration and frequency during work and the other 17 related ergonomic issues in 606 healthy maintenance men.** ***Results*** **The high risk sites of work-related musculoskeletal disorders in maintenance men of civil aviation was back, followed by neck, shoulder, right wrist and knees. The high risk site of work-related musculoskeletal disorders in aviation machinery maintenance workers (ME) was back. As to the avionics maintenance worker (AV) the high risk site was neck. The ergonomic factors were different with workers in wide cabin and thin cabin.** ***Conclusion*** **The ergonomic risk factors come from mainly discomfort posture and repetitive overload operations. BRIEF and PLIBEL are effective methods to evaluate musculoskeletal disorders. The management and control on the ergonomic risk factors should be strengthened for preventing the work-related musculoskeletal disorders of civil aviation maintenance men.**

Keywords—work-related musculoskeletal disorders (WMSDs), ergonomics, civil aviation maintenance men, BRIEF, PLIBEL

I. INTRODUCTION

Musculoskeletal disorders (MSDs) are injuries and/or functional disorders affecting muscles, bones, nerves, tendons, ligaments, joints, cartilage and intervertebral discs. MSDs in the United States, Germany and other industrial developed countries is a statutory occupational disease. It is a work-related disease in China[1].

Civil aviation maintenance personnel have the important task of ensuring flight safety. With the rapid growth of civil aviation traffic the maintenance and support tasks are becoming more and more demanding. Civil aviation maintenance personnel have great responsibility. Their bodies are often in a state of high concentration, fixed posture, repetitive or continuous work, coupled with outdoor working environment, high temperature and cold, noise, vibration, shift and psychological stress. Musculoskeletal disease (WMSDs) is an important problem that cannot be ignored for civil aviation maintenance personnel. How to evaluate WMSDs related risk factors for this population is rarely reported. American BRIEF [2,3] and Swedish PLIBEL have been well applied in identifying and evaluating ergonomic hazard factors [4,5]. In this paper, two methods were adopted to identify and evaluate the adverse ergonomics factors that may be exposed to by maintenance personnel in a domestic maintenance unit. It will also provide scientific basis for prevention of WMSDs in this population.

II. OBJECTS AND METHODS

A. Objects

826 maintenance personnel from a maintenance unit were selected. Exclude those with previous medical history of trauma and musculoskeletal injury. Finally 606 health maintenance personnel were selected as research objects. Among them there are 456 aviation machinery (ME) maintenance workers and 150 avionics (AV) maintenance workers. Among aviation machinery maintenance personnel 228 are working on wide-body aircraft and 228 are working on narrow-body aircraft.

B. Methods

In this paper BRIEF and PLIBEL methods were adopted to conduct on-site inspection on the operation activities of the above-mentioned 606 healthy maintenance personnel. BRIEF examination includes 4 indicators of posture, strength, duration and movement frequency of the left and right wrists, elbows, shoulders and neck, back and legs, as shown in table I. PLIBEL examination contents include: body and neck and shoulders and back, elbows and forearms and hands, feet, knees and hips, lower back 5 parts involving posture, movement and use of tools, organizational and environmental factors.

BRIEF checklist is an overall survey and observation of the posture, strength, duration and movement frequency of the left and right wrists, elbows, shoulders and neck, back and legs. Judge the risk by the score. There are 4 indexes for

each part. Each item counts 1 point and 4 points at most. The two sub-indexes of posture and strength in the four indexes will have multiple survey contents in different parts of the body. As long as there is one sub-index, the sub-index will be marked as 1 point. Generally the score ≥2 points is the criterion to determine the risk. In this paper multiple objects were observed in the same operation and the majority of people were ≥2. Then the weighted score (weighted value of average score and number of people) of risk factors was adjusted to be ≥1.5.

Weighted value of average score:

$$\overline{x} = \frac{x_1\omega_1 + x_2\omega_2 + ... + x_n\omega_n}{\omega_1 + \omega_2 + ... + \omega_n} \quad (1)$$

TABLE I. CHECKLIST OF BASIC ELEMENTS OF AMERICAN ERGONOMICS (BRIEF)

	Left			Right					
	Wrist	**Elbow**	**Shoulder**	**Wrist**	**Elbow**	**Shoulder**	**Neck**	**Back**	**Leg**
Posture	Pinch grip □	Forearm rotation□	≧45°□	Pinch grip □	Forearm rotation□	≧45°□	≧20° □	≧20° □	squat□
	finger press□	fully extented□	reach back □	finger press □	fully extented□	reach back □	sideways□	twist□	Einbeinig □
	radial deviation □			radial deviation □			backwards □	sideways □	kneel□
	ulnar deviation □			ulnar deviation □			twist□		
	bend ≧45°□			bend ≧45°□					
	Dorsal stretch ≧ 45°□			Dorsal stretch ≧ 45°□					
Strength （kg）	Pinch grip ≧ 0.9 □	≧4.5□	≧4.5□	Pinch grip ≧ 0.9□	≧4.5□	≧4.5□	bear load□	≧9□	foot ≧ 4.5 □
	grab ≧4.5□			grab ≧4.5□					
Time of duration （s）	≧10□		≧10□	≧10□		≧10□	≧10□	≧10□	≧30%/日 □
Frequency （Times/min）	≧30□	≧2□	≧2□	≧30□	≧2□	≧2□	≧2□	≧2□	≧2□

PLIBEL checklist is a method to comprehensively judge and evaluate the ergonomic risk factors of WMSDs of different parts of the body based on interviews and observations on 17 aspects related to posture, activity and use of tools, organization and environmental factors.

The entire investigation and observation was conducted by trained and qualified investigators. The observed activity cycles were 5 at least. Conduct pre-inspection of representative operators and activities. Standardize and unify the criteria and methods for different inspection items.

III. RESULTS

A. General characteristics of objects

TABLE II. OBSERVATION OBJECT

Group	The number of object	Percentage (%)
Gender		
Male	497	82.01
Female	109	17.99
Age		
~ 25 years old	66	10.89
~ 35 years old	215	35.48
~ 45 years old	278	45.87
> 45 years old	47	7.76
Position		
Aviation machinery maintenance personnel	456	75.25
Avionics maintenance personnel	150	24.75

The 606 aircraft maintenance men cover aviation machinery (ME) maintenance personnel and avionics (AV) maintenance personnel. There are 497 males (82.01%) and 109 females (17.99%). The age range is 22.0 to 59.0 (39.4±5.0) years and the working age is 6.2 (0.1 ~ 28.0) years. The distribution of their personality characteristics is shown in table II.

B. Reslt of BRIEF

The observation results of 606 aircraft maintenance personnel using the American BRIEF method are shown in table III.

In the four indexes of posture, strength, duration and movement frequency in the maintenance crew, the highest points were concentrated in the neck and back respectively with scores>2 points. Aviation machinery maintenance personnel (ME) have the back (2.0 points), neck (2.0 points)， the right wrist (1.5 points) and leg (1.5 points) for the parts whose scores exceed 1.5 points. Avionics maintenance personnel (AV) only have neck (2.1 points)and right shoulder (1.7 points) whose scores exceed 1.5 points. T test was used to determine the score difference between groups. The significance test of each operating score showed that the scores of aviation machinery maintenance workers were significantly higher than those of avionics maintenance workers in back, neck, waist, shoulder and right wrist ($P<0.05$).

Aviation machinery maintenance men are divided into narrow-body aircraft maintenance personnel and wide-body aircraft maintenance personnel. The highest score parts of aviation machinery maintenance workers of wide-body aircraft are neck and back while the highest score part of

aviation machinery maintenance workers of narrow-body aircraft is shoulder. The result is shown in table IV.

TABLE III. BRIEF SCORE FOR CIVIL AVIATION MAINTENANCE PERSONNEL (WEIGHTED SCORE)

Job	Left wrist	Left elbow	Left shoulder	Right wrist	Right elbow	Right shoulder	Neck	Shoulder	Back
ME	0.3	0.4	1.1	1.5	0.5	1.0	2.0	2.0	1.7
AV	0.3	0.4	1.0	1.4	1.2	1.7	2.1	1.3	0.6

ME: AVIATION MACHINERY MAINTENANCE PERSONNEL
AV: AVIONICS MAINTENANCE PERSONNEL

TABLE IV. AVIATION MACHINERY MAINTENANCE PERSONNEL BRIEF SCORE

Job	Left wrist	Left elbow	Left shoulder	Right wrist	Right elbow	Right shoulder	Neck	Shoulder	Back
Wide-body aircraft	0.3	0.4	1.1	0.4	0.5	1.2	2.0	1.9	1.6
Narrow-body aircraft	0.3	0.4	1.0	1.6	1.2	1.7	2.1	1.6	0.6

TABLE V. CIVIL AVIATION MAINTENANCE PERSONNEL PLIBEL INSPECTION RESULTS

Job	Neck shoulder upper back	Elbows, forearms and hands	Knees and hips	low back
ME				
Wide-body aircraft	4, 9a,9c,10a,10b,11b,11g,13, 14a,14b	12,13,14a,14b	6,8a	4,6,8a,9a,9c,11b,11g,12
Narrow-body aircraft	2,9b,9c,10a,10b,11b,11g,12,13,14a,14b	2,12,13,14a,14b	6,8a	2,6,8a,9b,9c,11b,11g,12
AV	15b,16	14a,15b,17a,17b		

ME: AVIATION MACHINERY MAINTENANCE PERSONNEL
AV: AVIONICS MAINTENANCE PERSONNEL

$$t = \frac{\bar{d} - \mu_0}{s_d / \sqrt{n}} \tag{2}$$

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n} \tag{3}$$

$$s_d = \sqrt{\frac{\sum_{i=1}^{n} \left(d_i - \bar{d}\right)}{n-1}} \tag{4}$$

$i=1...n$

$\bar{d}$ *: Mean of the difference between the paired samples*

n: Number of paired samples

s_d *:Standard deviation of paired sample difference*

C. Reslt of PLIBEL

Sweden PLIBEL method was adopted to observe and test the 17 aspects of civil aviation maintenance personnel. Civil aviation maintenance personnel mainly have ergonomic problems such as using tools that are not easy to grasp, standing posture without support with back forward bend and twist, lifting and carrying with repeated or continuous load, repeatedly climbing ladder and stepping work. Due to the large space of wide-body aircraft, aviation machinery maintenance personnel are more prone to neck and upper back uncomfortable torsion. The narrow body aircraft space is narrow. Aviation machinery maintenance personnel's problem of operation in limited space is more serious. Due to less lifting, less weight, less twisting and rotation of the body, the ergonomics problems of avionics maintenance workers are relatively light. The result is shown in table V.

IV. CONCLUSION AND DISCUSSION

Civil aviation plays an increasingly important role in modern transportation. Aircraft maintenance personnel have the important task of aircraft maintenance and flight safety. With the rapid development of civil aviation, the requirement of flight support mission is higher and higher. The workload of aircraft crew is also increasing. WMSDs is a common disease among aircraft crew[6,7]. How to effectively reduce the occurrence of WMSDs and maintain the health of aircraft crew is an important content of civil aviation protection.

There are many classifications of civil aviation maintenance personnel. According to whether the workplace is indoor or outdoor, civil aviation maintenance personnel are divided into aviation field work and internal work. Personnel working in field are engaged in the flight line maintenance. The in-office staff work in the airline maintenance workshop. They are responsible for the third and fourth level maintenance of the aircraft, i.e. a major preventive inspection and necessary repair of the work items listed in the structure and system of the aircraft. The work movements of aircraft maintenance personnel in the field and in the office are similar, so the grouping adopted in this study is classified according to the civil aircraft maintenance personnel license of the civil aviation administration of China. Civil aviation administration of China divides civil aircraft maintenance personnel into aviation machinery (ME) maintenance personnel and avionics (AV) maintenance personnel. Each type of maintenance personnel is generally divided into wide-body aircraft maintenance personnel and narrow-body aircraft maintenance personnel according to maintenance models.

WMSDs reports on civil aviation maintenance personnel are rare. According to the BRIEF results of this study, the lower back is the main dangerous part of WMSDs for civil aviation maintenance personnel, especially for aviation machinery (ME) maintenance personnel. PLIBEL inspection results show that in aviation machinery (ME) maintenance personnel, no sitting and support posture operation (6), repeat climbing and step work (8a), back forward bend (9), neck twist (10), repeated support heavy weight (12), repetitive operation (14a) and other aviation maintenance personnel WMSDs operating factors. In the maintenance work of narrow-body machine there are still limited working

space (2) and in the maintenance work of wide-body machine there are also bad operating factors such as repetitive work (14b) beyond the comfortable extension range. Emphasis should be placed on controlling the above undesirable operations.

In addition to practical operational factors, studies[8,9] have shown that the risk factors of occupational chronic musculoskeletal injury also include personal factors, occupational factors and psychological factors. Civil aviation maintenance personnel shift frequently. Their natural laws of day and night are often disturbed which has different effects on sleep, diet, family life and social activities. In case of aircraft with major faults and defects to be eliminated, civil aviation maintenance personnel often have to work overtime, especially for overnight inspection. In order to eliminate shortcomings and defects they often work overtime until dawn. The working environment of civil aviation maintenance personnel is noisy, sultry or cold. They also have heavy work tasks and great responsibility. They are easy to cause psychological overload. These factors may be related to the chronic musculoskeletal injury of aviation maintenance personnel.

In summary, BRIEF and PLIBEL methods can be better used for the identification and evaluation of WMSDs ergonomic factors of civil aviation maintenance personnel. The main risk areas of skeletal muscle injury of civil aviation maintenance personnel are back, neck, shoulder and right wrist which vary from job to job. In view of other possible problems caused by WMSDs, such as the effect of cervical spondylosis on brain function, visual function and subsequent aviation safety issues [10], the authors suggest that the management and control of ergonomic risk factors for civil aviation maintenance personnel should be strengthened, such as reasonable arrangement of labor organization, correcting poor working posture, increasing the frequency of rest, providing training of ergonomic hazards and prevention methods.

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