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Research on Comprehensive Quantitative Evaluation System of Occupational Stress of Civil Aviation Pilots

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Abstract: Through theoretical analysis, expert survey and issuance of the questionnaire to all age civil aviation pilots this paper summarized several influential factors for occupational stress of civil aviation pilots and established an occupational stress risk comprehensive valuating index system. According to the comprehensive analysis of occupational stress influential factors we took 7 factors, i. e. working load factor, physiological factor, organization factor, psychological factor, environmental factor, equipment factor and incident factor as the criterion. Then an occupational stress risk comprehensive valuating index system was established. Order relation analysis method (G1 method) was used to calculate the weights of indexes. Thus occupational stress risk three grade comprehensive evaluation index system was established. To quantify the level occupational stress index by four levels each occupational stress index was respectively corresponded to different degrees of occupational stress. Civil aviation pilots occupational stress questionnaires are compiled according to the comprehensive evaluation index system. Through the questionnaire statistical analysis results of occupational stress index distribution value interval of occupational stress index corresponding to the degree of occupational stress for civil aviation pilots was divided reasonably which reflected the comprehensive quantitative evaluation of occupational stress. The results showed that the quantitative evaluation system provided a practical way for the evaluation of occupational stress level and risk for civil aviation pilots.

1. Introduction

With the rapid development of society and economy the air transport industry begins a golden period of rapid development. With the rapid development of the civil aviation transportation industry the operation environment is becoming more and more complex and the flight airspace is becoming more and more crowded. Aviation safety faces new challenges. When a transport airline pilot's job

goes wrong it can have very serious consequences. So the pressure on the pilot is enormous.

At home and abroad there are some reports on identifying and evaluating occupational stress with objective indicators, such as saliva cortisone, immunoglobulin A(sIgA), saliva lysozyme, salivary amylase, some monoamine hormones in the blood, NK cell activity, catecholamines in urine, 17-OHCS and 17-KS[1-5]. The study on objective evaluation index of occupational stress was carried out early and widely but few definite conclusions were drawn. The operation was a little complicated and there were many interference factors.

At present the main methods of identifying and evaluating occupational stress at home and abroad are psychological scale and questionnaire. Among the various models of occupational stress measurement the work demand-autonomy model tends to focus on the influence of external sources (such as work characteristics and work environment) on the individual. The payback imbalance model pays more attention to the influence of internal factors (such as the individual's cognitive giving and receiving) from the individual. Both of these modes of occupational stress have advantages and disadvantages. The work demand-autonomy model mainly includes a comprehensive assessment of the work environment but does not consider that different individuals may have different reactions under the same tension. The payback imbalance model explains different responses among individuals but it lacks an assessment of work tasks and autonomy. To address the shortcomings of each of these two modes of occupational stress the two models have been used to comprehensively evaluate individual occupational stress at home and abroad. Considering the occupational stress caused by different internal and external factors it can fully explain the social and psychological factors in the work process [6,7].

In fact most civil aviation managers do not have medical and public health knowledge. How to evaluate the occupational stress risk of civil aviation pilots in a quick, convenient and effective way and how to establish a scientific evaluation index system are the key problems in the evaluation of occupational stress risk of civil aviation pilots.

2. Object and methods

2.1. Object

By adopting cluster sampling civil aviation pilots of a domestic airline company were randomly selected as survey objects and self-test questionnaires were issued. The methods of self-report and investigator inquiry were adopted to conduct questionnaire survey on the research objects. In the introduction to the questionnaire the purpose and significance of the survey were explained in detail and the nature of the survey was voluntary participation. A total of 1087 questionnaires were collected among which 88 questionnaires had seriously missing items. So 999 valid questionnaires were obtained for analysis.

2.2. Methods

- Pilot stress questionnaire and regression analysis

If there is a linear correlation between the dependent variable Y and the independent variable X, that is to say, for a certain value of the independent variable X the value of the dependent variable Y is not unique. There are many possible values which are distributed above and below a line. The magnitude and direction of the influence of these factors are uncertain and are usually expressed by a random variable, also known as the random disturbance term. Therefore, the dependence between Y and X can be expressed as

$$y_i=\alpha+\beta x_i+\varepsilon_i \quad (1)$$

$$\hat{y}_i = a+bxi \quad (2)$$

$$\begin{cases} b=\dfrac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sum(x_i-\bar{x})^2}=\dfrac{n\sum x_i y_i-\sum x_i\sum y_i}{n\sum x_i^2-(\sum x_i)^2} \\ a=\dfrac{\sum y_i}{n}-b\times\dfrac{\sum x_i}{n}=\bar{y}-b\bar{x} \end{cases} \quad (3)$$

- Order relation analysis

30 occupational disease prevention and control experts, safety managers, human factors researchers and senior civil aviation pilots were invited to conduct questionnaire survey. Solicit and refine the opinions of expert groups. Screen and verify the factors that may induce the occupational stress of civil aviation pilots. By means of questionnaire survey, field survey and expert interview, on the basis of comprehensive analysis of the factors affecting occupational stress of civil aviation pilots, we selected the indicators that can comprehensively reflect the risk of occupational stress of civil aviation pilots and establish an evaluation index system. Order relation analysis (Gl) was used to determine the weight of each evaluation index. In order to facilitate calculation the third layer of sub-factors of civil aviation pilots' occupational stress risk index is graded and quantified. According to the established risk assessment system model of civil aviation pilots' occupational stress, the index score of civil aviation pilots' occupational stress risk can be calculated according to the index system by developing self-assessment questionnaire and using the weight value of the calculated indexes. Determine the value range of occupational stress risk of civil aviation pilots by statistical analysis. Finally we finished the comprehensive quantitative evaluation which can provide data support for the realization of civil aviation pilot occupational stress risk management.

- Rationale for risk assessment

There are many factors that affect occupational stress. It is fuzzy and difficult to quantify these factors. So we used order relation analysis method (G1 method) to assign weights to the indexes and then applied fuzzy relation synthesis principle to make multi-level fuzzy evaluation on the membership degree of occupational stress risk. Order relation analysis method G1 is an improved method of AHP method proposed by professor Yajun Guo of Northeastern University[8]. It overcomes the defect of AHP method. Each step of the method fully reflects the expert's wishes. The method is simple and practical with clear and definite process. There is no need to judge the matrix and no need to conduct consistency test.

- Definite order relation

If the importance of evaluation index x_i relative to an evaluation criterion is greater than x_j then it can be denoted as:

$$xi>xj \quad (4)$$

From the evaluation index set { x_1, x_2, …, x_m }, experts select one of the most important indicators and mark it as:

$$x\,1>x\,2>x3>x4\ldots>xm \quad (5)$$

Due to the subjective factors of experts the order relations determined by different experts are often different.

- Relative importance

For some problems it is not enough to give order relations. We also need to determine the weight coefficient of the evaluation index to a certain evaluation criterion and judge the relative importance

of x_{k-1} to x_k.

The ratio of importance is adopted to represent the experts' comparative judgment on the relative importance between adjacent indexes x_{k-1} and x_k:

$$rk = \omega k\text{-}1 \ \omega k\text{-}1 (k = m, m\text{-}1, m\text{-}2, \ldots 3, 2) \quad (6)$$

Table 1: r_k assignment table

r_k	Degree of importance
1.0	x_{k-1} is just as important as x_k
1.2	x_{k-1} is slightly more important than x_k
1.4	x_{k-1} significantly more important than x_k
1.6	x_{k-1} is more important than the x_k
1.8	x_{k-1} is extremely important than x_k

- Weight coefficient

If the r_k rational assignment given by experts (or decision makers) meets the requirements in table 1, then ω_k is:

$$\omega_m = \left[1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i\right]^{-1} \quad (7)$$

$$\omega_{k-1} = r_k \omega_k \quad (8)$$

3. Results

3.1. General characteristics of objects

A total of 1,087 questionnaires were distributed to civil aviation pilots of an airline company in China. 999 valid questionnaires were collected and the effective recovery rate was 91.90%. Of 999 respondents there are 928(92.89%) male and 71 (7.11%) female. Their age is 22.0~60.0(39.4±5.0) years. Their working years *M* is 13.2(0.1~28.0) years.

3.2. Occupational stress risk assessment index system

The causes of occupational stress are diverse. There are many factors affecting occupational stress and the interaction mechanism is complex. In order to summarize the factors that affect the career stress of civil aviation pilots from a systematic point of view we referred to domestic and foreign literature to summarize the factors that may lead to occupational stress. Then 30 occupational disease prevention and control experts, safety managers, human factors researchers and senior civil aviation pilots were invited to conduct questionnaire survey. We solicited and refined the opinions of expert groups. We screened and verified the factors that may induce occupational stress of civil aviation pilots. Taking environmental factor, equipment factor, work factor, event factor, management factor, physiological factor and psychological factor into comprehensive consideration, the risk evaluation index system of occupational stress of civil aviation pilots was established, as shown in Fig. 1.

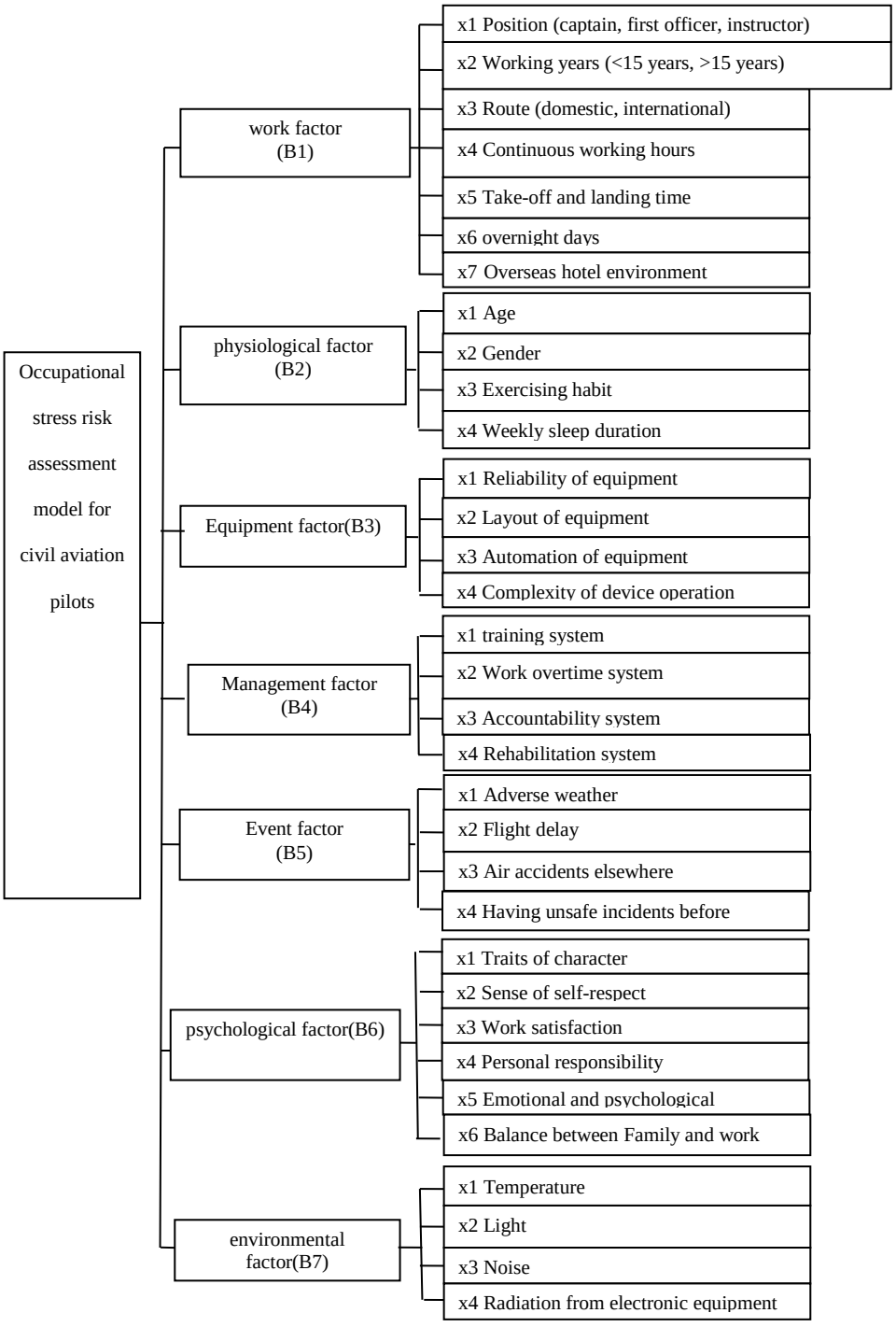

Figure 1: Index weight of occupational stress risk assessment of civil aviation pilots

3.3. Determine the index weight of the evaluation index system of occupational stress of civil aviation pilots

According to the above-mentioned evaluation index system of occupational stress risk of civil aviation pilots the expert consultation questionnaire was developed according to the requirements of Gl method. Experts were invited to sort each layer of indicators first and then give the importance evaluation between two indicators. We consulted a total of 30 experts, 26 of whom answered the

questionnaire effectively. According to the ranking and importance comparison of indicators of each layer by experts G1 method was adopted to determine the weights of indicators of each layer. Table 2 shows the calculation results of the weights of secondary and tertiary indicators.

Table 2: Index weight table of occupational stress risk assessment of civil aviation pilots

Second indicators	Third indicators	Index weight
Work factor (0.2766)	x1 Position (captain, first officer, instructor)	0.1265
	x2 Working years (<15 years, >15 years)	0.1124
	x3 Route (domestic, international)	0.1288
	x4 Continuous working hours	0.1361
	x5 Take-off and landing time	0.1573
	x6 overnight days	0.2231
	x7 Overseas hotel environment	0.1158
Physiological factor (0.1243)	x1 Age	0.1730
	x2 Gender	0.0851
	x3 Exercising habit	0.1265
	x4 Weekly sleep duration	0.3167
	x5 Daily sleep duration	0.2987
Equipment factor (0.0582)	x1 Reliability of equipment	0.2983
	x2 Layout of equipment	0.2656
	x3 Automation of equipment	0.1340
	x4 Complexity of device operation	0.3021
Management factor (0.1253)	x1 training system	0.3144
	x2 Work overtime system	0.2481
	x3 Accountability system	0.2841
	x4 Rehabilitation system	0.1534
Event factor (0.1362)	x1 Adverse weather	0.3108
	x2 Flight delay	0.3421
	x3 Air accidents elsewhere	0.1215
	x4 Having unsafe incidents before	0.2256
Psychological factor (0.2385)	x1 Traits of character	0.1832
	x2 Sense of self-respect	0.0998
	x3 Work satisfaction	0.2163
	x4 Personal responsibility/expectation	0.1647
	x5 Emotional and psychological control	0.1632
	x6 Balance between Family and work	0.1728
Environmental factor (0.0409)	x1 Temperature	0.2651
	x2 Light	0.2365
	x3 Noise	0.2863
	x4 Radiation from electronic equipment	0.2121

3.4. Evaluation index model of occupational stress risk of civil aviation pilots

In order to facilitate calculation the indexes of the second layer of factors were graded and were divided into four grades (0 to 3). Each occupational stress index corresponded to different levels of stress. The grading results were shown in table 3.

According to the risk evaluation index system of occupational stress of civil aviation pilots established above the self-test questionnaire of occupational stress of civil aviation pilots was developed. Then we issued self-test questionnaire to civil aviation pilots of an airline company of

CAAC. A total of 1087 questionnaires were issued, among which 88 questionnaires had seriously missing items. So 999 questionnaires were valid for analysis. According to the Chinese version of Job content Questionnaire (JCQ), occupational stress grading intervals can be divided, and the results are shown in table 4.

Table 3: Corresponding table of occupational stress degree of civil aviation pilots

Risk indicator	Degree of stress
3	High pressure
2	Moderate tension
1	Mild tension
0	No tension

Table 4: Results of division of occupational stress interval

Degree of occupational stress	High pressure	Moderate tension	Mild tension	No tension
Occupational Stress Indicator	[2.3406,3)	[1.2823,2.3406)	[0.2721,1.2823)	[0,0.2721)

4. Conclusion and discussions

Occupational stress is the physical and psychological stress caused by the imbalance between objective needs and individual adaptability in certain occupational conditions. The loss caused by occupational stress is huge. Long-term high intensity occupational stress will have a serious impact on workers' health and work efficiency[9]. Occupational stress also causes economic losses to enterprises and society[10].

Because of complicated working environment and huge safety responsibility civil aviation pilots have different occupational stress problems and influences from other occupations. The cause of civil aviation pilots' occupational stress is not only from the objective work but also from internal influence. The purpose of understanding the occupational tension of civil aviation pilots and its influencing factors is to relieve or reduce the tension as much as possible so as to maximize their work quality and maintain aviation safety. At present, the questionnaire of occupational stress assessment at home and abroad lacks pertinence to the actual working and living factors of civil aviation pilots. This study established the civil aviation civil aviation pilot occupational stress risk evaluation index system from the work factor, physical factor, management factor, psychological factor, environmental factor, equipment factor and events factor. According to G1 method to determine the index weight and through questionnaires, we established the effective civil aviation pilots occupational stress risk evaluation system.

The results of this study showed that among the seven secondary factors the impact of occupational stress on civil aviation pilots from heavy to light is work factor, psychological factor, event factor, management factor, physiological factor, equipment factor and environmental factor.

Overwork is an occupational risk factor for job stress[11,12]. This study showed that the number of overnight days, time of take-off and landing, continuous working hours and route types have the greatest impact on occupational stress of civil aviation pilots. These are all directly related to the task of civilian pilots. The results of this study also showed the regional stress of civil aviation pilots. In Beijing, Shanghai, Guangzhou and other areas with large traffic flow and complex airspace structure civil aviation pilots had more serious occupational stress.

The research results of Wuhong Lu [13] and Li Kang [14] showed that the occupational tension of

coal mine workers and flight attendants with high professional titles and long working years is high. Different from the above results this study showed that the occupational stress of civil aviation pilots with short working years is higher than that of pilots with long working years. The difference may be due to the nature of the work. Older pilots tend to have a lot of experience. They can meet the requirements of the job easily and have relatively high work autonomy. They are easy to get social recognition. So the degree of occupational stress is relatively low. Young pilots are lack of experience and have low social support and recognition. They also have less psychological and material returns. Pilots with short working years cannot meet psychological expectations. So their occupational tension is high.

Psychological factors are also important factors affecting the career stress of civil aviation pilots. Low job satisfaction, low family/work balance and low self-esteem are risk factors for occupational stress. Due to the long working hours and the nature of flying across time zones pilots do not spend much time with their families. The imbalance between home and work can lead to depression and mood disorders. Strong personality, competitiveness, desire for success, aggression, feeling pressed for time and responsibility are risk factors for career stress. We should undertake psychological quality examination in civil aviation pilot choosing.

Adverse weather, flight delays, accidents in other places, unsafe incidents before also affect the professional tension of civil aviation pilots. In order for aviation safety it is necessary to change its flight path or make a forced landing in bad weather. Then pilots can't take breaks on time. Bad weather could also delay flights until the weather improves and aircraft take off again. This increases the number of ups and downs. It also adds more work to pilots. Then civil aviation pilots' work load and pressure increase.

The management system of the unit is the fourth factor that affects the professional tension of civil aviation pilots. For civil aviation pilots ensuring flight safety is the most important. Once mistakes are made pilots will not only be severely punished but also bear economic and legal responsibilities. Such a large amount of work pressure makes pilots in a high tension for a long time. Frequent training makes the training task of civil aviation pilots onerous and affects the rest of civil aviation pilots. Some civil aviation pilots have negative views on regular training and adopt a negative attitude towards regular training. Not seriously participating in regular training often leads to their inability to competent work then these pilots will experience more professional stress. However, some pilots hold the point that the lack of training is an important reason for new employees' tension. Even old employees need to relearn and train for new technologies to improve their competitiveness and reduce tension.

Among the physiological factors weekly sleep duration and daily sleep duration have the greatest influence on occupational stress of civil aviation pilots. Lack of sleep can lead to a variety of physical and psychological stress, which is an important factor in career stress[15,16]. Li Kang[14] reported that the crew members with more night duty times and longer monthly duty times had higher daily stress scores. Occupational stress can also cause sleep disorders[17,18]. They reinforce each other.

Although the reliability of equipment, layout of equipment, automation degree of equipment, complexity of equipment operation, temperature, light, noise, radiation of electronic equipment and other factors have a relatively low impact on the occupational tension of civil aviation pilots, managers still should pay attention to adjustment of workplace microenvironment.

The study showed that the risk level of occupational stress of civil aviation pilots can be quantitatively determined by this model. This model can provide reliable reference and basis for relevant units to make reasonable work plan. This model can also help relevant units to relieve pilots' tension as much as possible so as to maximize their work quality and maintain aviation safety

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