La Medicina del Lavoro

Med Lav 2019; 110, 5: 389-397
DOI: 10.23749/mdl.v110i5.8115

Assessment of mental workload and its association with work ability in control room operators

Fatemeh Kamari Ghanavati[1], Alireza Choobineh[2], Sareh Keshavarzi[3], Ali Asghar Nasihatkon[4], Akram Sadat Jafari Roodbandi[5]

[1]Department of Occupational Health Engineering, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Research Center for Health Sciences, Institute of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[3]Department of Epidemiology, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[4]Petroleum Industry Health Organization, Medical Education and Research Center, Shiraz, Iran
[5]Ph.D. by Research Student, Research Center for Health Sciences, Institute of Health, Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran

Key words: Mental workload; NASA-TLX; work ability; control room

Parole chiave: Carico di lavoro mentale; NASA-TLX; capacità lavorativa; sala di controllo

Summary

Background: *Modern technology has reduced physical workload and imposed high mental workload on the control room operators in industrial settings. The present study was conducted among control room operators to assess their mental workload, investigate their workability, examine the relationship between mental workload and workability, and determine the factors associated with workability.* **Methods**: *This cross-sectional study was carried out among 213 control room operators in six Iranian process industries. Task Load Index (NASA-TLX) was used to assess the mental workload, and Work Ability Index (WAI) was used to determine workability. The relationships between demographic characteristics and dimensions of mental workload and workability were examined by univariate tests. Logistic regression analysis was also used to determine the factors associated with the operators' workability.* **Results**: *The results showed a high mental workload in the study population (82.38±8.8). Yet, the operators showed a good and excellent level of workability (56.4%). Pearson's correlation coefficient revealed a significant inverse linear relationship between the mean score of mental workload and workability (r=-0.581). Besides, regression modeling demonstrated that mental demand (OR=0.90), temporal demand (OR=0.90), effort (OR=0.91), frustration (OR=0.92), from NASA-TLX subscales were significantly associated with workability. Moreover, mental and temporal demands were important factors associated with reduced workability.* **Conclusion:** *Monitoring tasks imposes high mental workload on the control room operators, which may result in adverse effects on their workability as well as on the safety of the system.*

Riassunto

***«Valutazione del carico di lavoro mentale in associazione con la capacità lavorativa in operatori di sala di controllo»*.** **Introduzione:** *Le moderne tecnologie hanno ridotto il carico di lavoro fisico ma, parallelamente, hanno imposto un alto (o aumentato il) carico di lavoro mentale negli operatori di sala di controllo in contesti industriali. Il presente studio è stato condotto tra operatori di sala di controllo per valutare il carico di lavoro mentale e la capacità lavorativa, esaminare la relazione tra carico di lavoro mentale e capacità lavorativa, e determinare i fattori associate*

Pervenuto il 17.1.2019 - Revisione pervenuta il 7.9.2019 - Accettato il 30.9.2019
Corrispondenza: Akram Sadat Jafari Roodbandi, Research Center for Health Sciences, Shiraz, University of Medical Sciences, Shiraz, Iran, P. O. Box: 7153675541 - Tel. +98 9163418479 - Fax +98 71 37260225 - E-mail: a_jafari@sums.ac.ir

con la capacità lavorativa. **Metodi**: *Uno studio trasversale è stato condotto su 213 operatori di sala di controllo in sei industrie di trasformazione iraniane.. Il Task Load Index (NASA-TLX) è stato impiegato per valutare il carico di lavoro mentale, mente il Work Ability Index (WAI) è stato usato per determinare la capacità lavorativa. Le relazioni tra caratteristiche demografiche e dimensioni di carico di lavoro mentale e capacità lavorativa sono state analizzate attraverso test univariati. L'analisi di regressione logistica è stata usata per determinare I fattori associate con la capacità lavorativa degli operatori.* **Risultati**: *I risultati mostrano un alto carico di lavoro mentale nella popolazione studiata (82.38±8.8). Tuttavia, gli operatori hanno mostrato buoni ed eccellenti livelli di capacità lavorativa (56.4%). L'indice di correlazione di Pearson ha mostrato una significativa relazione inversamente lineare tra lo score medio del carico di lavoro mentale e la capacità lavorativa (r=-0.581). Inoltre, il modello di regression ha dimostrato che esigenze mentali (OR=0.90), esigenze temporali (OR=0.90), sforzo (OR=0.91), frustrazione (OR=0.92), delle sottoscale NASA-TLX erano significativamente associate con la capacità lavorativa. Infine, le esigenze mentali e temporali erano importanti fattori associati con una ridotta capacità lavorativa.* **Conclusioni**: *Monitorare i compiti assegnati impone un alto carico di lavoro mentale negli operatori di sala di controllo, che può avere effetti negativi sulla loro capaictà lavorativa e sulla sicurezza del Sistema.*

Introduction

With the rapid advancement of technology, complex work systems have appeared in industries (25), resulting in increased mental workload (24). In many industrial settings, such as nuclear, chemical, military, and medical industries, critical systems with advanced technologies are used (11). Controlling modern complex systems often imposes heavy mental workload on operators (18), which influences their performance and safety. In other words, the operators' performance is associated with their mental workload in such a way that the best performance occurs at an acceptable level of mental workload (31, 34).

Mental workload refers to the effort made by the mind while doing tasks (43) Quick and affordable subjective self-report tools such as NASA-TLX are used for mental workload assessment in employees whose occupation requires high mental accuracy, speed of action, and controlling tasks with critical decision-making (7). Under excessive mental workload, human operators may experience delays in processing the information. Indeed, they may not be able to respond to input data because the amount of data is higher than their processing capacity, which can reduce their judgment and decision-making abilities while performing the task (34). In other words, high mental workload is accompanied with reduced work ability and performance (26). Some studies suggested that too high or low mental workload will result in the decline of employee's work ability (38, 46). Work ability describes an operator's capacities and capabilities with regard to physical and psychosocial demands. Work ability is a complex concept, which can be affected by individual, social, and work-environment factors (19). Strengthening the work ability is one way to increase the efficiency of human resources in industries and organizations (2). Work ability is also an important factor in identifying the workers who are at risk of imbalance among health, ability, and professional needs (42).

Employees with capabilities to meet their job requirements are less likely to err (37). In other words, if workers' physical and mental capabilities do not conform to their job requirements, safety problems, reduced production, and increased work force turnover are expected (28). This issue is of particular importance for individuals working in high technology settings, such as nuclear power plants and other process industries (37). Health and work ability are important factors in workers' occupational safety in these processing industries (10). In the control room, operators should receive and process large amounts of data in a short period of time and make decisions accordingly. It is clear that catastrophic accidents may take place where errors occur in such decision-making situations (48). Accidents in complex systems not only cause large financial losses, but they can also be life-threatening (14). In 1994, the explosion and fire in Texaco refinery killed 24 individuals and resulted in damage equal to 48 million pounds. This is an example of such accidents, which occurred due to human error, where the control room operator had to recognize and take appropriate measures for 275 alarms 11 minutes before the explosion (45).

Many subjective procedures exist to measure the mental workload, such as Cooper-Harper Scale, Bedford Scale, Subjective Workload Assessment Technique (SWAT), and Task Load Index (NASA-TLX) (26). NASA-TLX and SWAT are largely used in many fields, such as aeronautics (8) and surgery (30). NASA-TLX is more acceptable to participants and is more sensitive to mental workload differences, particularly at low workload levels (39), but the researcher has used NASA-TLX in a study in which the participants have a high-level of mental workload (5, 6, 39).

Studies have shown that mental workload may lead to mental job stress (9), that, in turn, increases human errors (28) and reduces work force's productivity (16). The severe consequences of accidents in the above-mentioned industries and the critical role of human factors in the control room of complex industrial enterprises, which is regarded as the beating heart of the system, on the one hand, and the fact that control room operators have important roles in preventing errors and human and financial damages as well as infra-organizational threats on the other hand lead us to this point that assessment, maintenance, and improvement of the employees' work ability is of great importance in order to increase productivity and prevent the employees' early retirement.

Since no studies have been carried out so far to assess the mental workload and work ability in the control room operators in Iran, the present study was conducted among the control room operators of Iranian process industries with the following objectives:

a) To assess mental workload,

b) To investigate the operators' work ability,

c) To examine the relationship between mental workload and work ability, and

d) To determine the factors associated with the operators' work ability.

Methods

This cross-sectional study was conducted on the control room operators of six process industries, including oil, gas, petrochemical, and power plants, in Fars, Bushehr, and Khuzestan provinces located in the south of Iran from January to June 2015. In this study, 213 male operators with at least one year of job tenure were selected through consensus. All subjects signed informed consent forms before commencement of the study. The study protocol was reviewed and approved by the Ethics Committee of Shiraz University of Medical Sciences.

Data gathering tools

The required data were collected through anonymous self-administered questionnaires. A demographic questionnaire was used to collect personal details, including age, weight, height, Body Mass Index (BMI), job tenure, daily working time, marital status, education level, type of employment, pre-employment specialized training, and working schedule.

To assess the mental workload, NASA-TLX was applied. It is a well-known self-report index developed by Hart and Staveland in 1998 (15). This index is calculated in two steps. First, the participants are asked to complete a pair-wise comparison process in order to give weight to six subscales or dimensions of mental demands, physical demands, temporal (time) demands, performance, effort, and frustration. Second, they are requested to determine a score in a 0-100 scale. The final score of the index is obtained using a formula and by combining the two steps. The face validity of NASA-TLX has been verified in previous studies (29).

In order to determine work ability, we used Work Ability Index (WAI). This index was developed by Ilmarinen at the Finnish Institute of Occupational Health (FIOH) based on a theoretical model of work ability (40). The instrument consists of seven items, each of which is assessed using one or more questions. This index is calculated using the sum of the scores obtained for each item as follows:

1. Current work ability compared to the lifetime best (0-10 points)
2. Work ability in relation to demands of the job (2-10 points)
3. Number of current diseases diagnosed by a physician (1-7 points)
4. Estimated work impairment due to diseases (1-6 points)
5. Sick leave during the past 12 months (1-5 points)
6. Personal prognosis of work ability in two years from now (1, 4, and 7 points)
7. Mental resources referring to the worker's life in general, both at work and during the leisure time (1-4 points).

The WAI score ranges from 7 to 49, with higher scores indicating better work ability. Accordingly, scores 7-27, 28-36, 37-43, and 44-49 represent poor, moderate, good, and excellent work abilities, respectively. The validity and reliability of the Persian version of the questionnaire were examined by Abdolalizadeh et al. in Iran (1).

The participants were provided with the questionnaires in their workplace. They were required to complete the questionnaires while performing their jobs during their work shifts in the presence of the researchers.

Data analysis

Statistical analyses were performed using the SPSS statistical software, version 19. Descriptive statistics, including mean and Standard Deviation (SD), were used to describe the variables. Using Kolmogorov-Smirnov test, we examined the normal distribution of the data. Then, t-test was used to compare the quantitative variables with two independent qualitative groups. Besides, ANOVA was used to compare the means of the quantitative variables with more than two qualitative groups. Chi-square test was also used to compare qualitative variables. Pearson's correlation test was used to examine the relationship between quantitative variables, such as mental workload and work ability scores. Indeed, logistic regression analysis was used to determine the factors associated with the operators' work ability. In this regard, variables with $p \leq 0.25$ in univariate analysis were entered into the regression model (21). In all tests, the significance level was set at 0.05.

Results

The demographic characteristics of the control room operators who participated in the study are summarized in table 1.

NASA-TLX

The results of NASA-TLX questionnaire are presented in table 2. With respect to various dimensions of NASA-TLX, the minimum and maximum scores were related to 'physical demand' and 'mental demand' dimensions, respectively. The total mean score of NASA-TLX was 82.38.

The results of ANOVA, independent sample t-test, and correlation coefficient showed that the mean score of NASA-TLX was significantly influenced by BMI (p=0.002), nurture of job (p=0.011), pre-employment specialized training (p=0.031), and education level (p=0.043).

Work Ability Index (WAI)

The mean score of WAI was 36.82±5.33, which placed the participants in the good work ability group. The distribution of work ability levels among the operators is presented in table 3. Accordingly, 4.2% of the participants scored below 27 (poor work ability), 39.4% scored 28-36 (moderate work ability), 48.8% scored 37-44 (good work ability), and 7.5% scored 44-49 (excellent work ability). Thus, 43.6% of the studied participants were at the poor-moderate level of work ability.

The results of ANOVA indicated the influence of BMI (p=0.003) on WAI. The results of chi-square test also showed that WAI was significantly influenced by the type of employment (p=0.008) and education level (p=0.036). Also, there was no significant relationship between the mean age and different levels of work ability (P=0.371) Therefore, different age groups were not compared with the level of work ability.

Table 1 - Demographic characteristics of the operators under the study (n=213)

Age (years)	Mean (SD) Min-Max	34.98 (6.81) 24-59
Job tenure (years)	Mean (SD) Min-Max	10.16 (6.75) 1-32
Height (cm)	Mean (SD) Min-Max	176.22 (6.45) 154-191
Weight (kg)	Mean (SD) Min-Max	80.53 (11.02) 53-122
BMI (Kg/m^2)	Mean (SD) Min-Max	25.9 (3) 17.36-34.89
Type of employment	Formal (%) Contractual (%)	184 (86.4) 29 (13.6)
Marital status	Single (%) Married (%) Others (%)	52 (24.4) 159 (76.4) 2 (0.9)
Education level	Diploma (%) A.D. (%) B.Sc. (%)	22 (10.3) 9 (4.2) 182 (85.5)
Pre-employment specialized training*	Yes (%) No (%)	199 (93.4) 14 (6.6)
Daily working time (hrs)	8‡ (%) 12† (%)	121 (56.8) 92 (43.2)
Working schedule	2 weeks work - 2 weeks rest† (%) 1 week work - 1 week rest† (%) 3 weeks work - 1 week rest† (%) 2 weeks work - 1 week rest† (%) 3 shifts work - 4 days rest‡ (%) 3 days work - 2 days rest‡ (%)	64 (30) 13 (6.1) 10 (4.7) 5 (2.3) 78 (36.6) 43 (20.2)

* Training given to the operators before starting their routine jobs in the control room
‡ 8-hour shift
† 12-hour shift

The correlation between NASA-TLX and WAI scores

In order to examine the correlation between the mean scores of mental workload (NASA-TLX) and work ability (WAI), we used Pearson's correlation test. The correlation coefficient (-0.581) represented a significant negative correlation between these two indices (p=0.0001). The mean scores of mental workload (NASA-TLX) at different levels of work ability are shown in figure 1. Accordingly, an increase in mental workload was accompanied with a decrease in work ability.

Factors associated with workability

To determine the factors affecting work ability using logistic regression analysis, we classified the response variables into high (excellent and good levels) and low work ability (moderate and poor) categories. According to the results of ANOVA and chi-square tests, pre-employment special-

Table 2. Mean ± SD and min-max scores of NASA-TLX dimensions among the operators (n=213)

Workload dimensions	Mean	SD	Min	Max
Mental demand	92.25	11.03	35	100
Physical demand	36.15	19.69	0	90
Temporal demand	86.45	13.31	25	100
Performance	80.68	12.88	30	100
Frustration	86.13	13.75	30	100
Effort	59.30	25.64	0	100
Total workload	82.38	8.89	49.66	100

Table 3. Distribution of the operators in different categories of work ability (n=213)

Levels of work ability	N (%)
Poor (7-27)	9 (4.2)
Moderate (28-36)	84 (39.4)
Good (37-43)	104 (48.8)
Excellent (44-49)	16 (7.6)

ized training, education level, marital status, type of employment, BMI, and daily working hours as well as mental demand, physical demand, temporal demand, effort, and frustration from NASA-TLX subscales were eligible to enter the logistic regression model ($p<0.25$). After adjusting for the potential confounding factors, logistic regression modeling showed that mental demand, temporal demand, effort, and frustration were significantly associated with work ability ($p<0.05$) (table 4).

Discussion

The mean score of NASA-TLX indicated that the control room operators' mental workload was higher compared to those reported in other studies conducted on other job groups (7, 27, 35). The reason could be attributed to the nature of the job, sensitivity of the tasks, and the utilized equipment and systems (22). In the present study setting, the physical workload was low, while the mental workload was high.

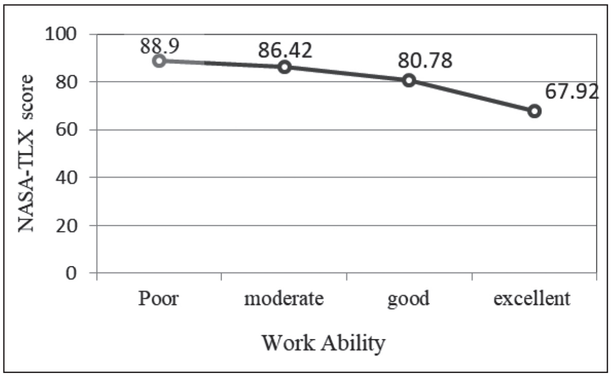

Figure 1 - Mean scores of mental workload in different categories of work ability

The mean score of WAI was classified as 'good' (WAI >36), which is in line with the results of other studies conducted in Iranian petrochemical industry and Croatian oil industry (3, 10, 28). Although the mean score of WAI was at the good level, 43.6% of the participants were at the poor-moderate level.

The study results supported the hypothesis that mental workload adversely affected work ability, in such a way that increase in mental workload was associated with reduced work ability. Xiao et al. showed that when mental workload was high, work ability was negatively correlated to mental workload (46). Safari et al. also showed in their study that low mental workload at work was directly related to higher work ability (36). This indicates the necessity to match the individuals' capabilities with their job requirements (26).

Based on the results of logistic regression analysis, mental demand, temporal demand, effort, and frustration had the strongest influence on the op-

Table 4. Models indicating the factors affecting the operators' work ability (n=213)

Dimensions	OR ($CI_{0.95}$)	B (SE)	Wald	P-value
Mental demand	0.896 (0.84-0.95)	-0.11 (0.032)	11.73	0.001
Temporal demand	0.899 (0.84-0.95)	-0.16 (0.031)	11.21	0.001
Effort	0.913 (0.86-0.96)	-0.091 (0.029)	9.98	0.002
Frustration	0.917 (0.87-0.96)	-0.087 (0/027)	10.77	0.001

erators' work ability. The results also showed a significant relationship between mental demand and work ability. An inverse relationship was also found between mental demand and work ability, which is in line with the results of other studies (33, 38, 40, 41). Because of the individuals' limited capacity of attention resources, as job demands begin to exceed their capacity limits, skilled operators tend to use compensatory strategies to adjust themselves to the required job demands (6). Studies have shown that when job demands exceeded the subjects' capabilities, a decrease was observed in their judgment and decision-making abilities, which could eventually result in the loss of work ability.

The current study findings revealed a significant negative association between temporal demand and work ability. This finding is in agreement with that of the study by Heansen et al., which demonstrated that time pressure was effective in work ability (13). Other studies have also shown time pressure as one of the factors that could predict work ability (18). These results were also in line with those of the research by Ilmarinen, which revealed low work ability in the subjects who worked under time pressure (20). Time pressure has been proved to be one of the most common stressors in the work environment, which leads to highly emotional reactions. More specifically, individuals' experiences would raise anxiety, causing more attention resources to be allocated to the task, thereby increasing the cognitive load (8).

The present study results showed a significant negative correlation between the 'effort' dimension in NASA-TLX and work ability. Effort means that a person has to work hard to accomplish one's level of performance (15). Since the nature of the control room operators' job was mental (rather than physical), the majority of the participants focused on the mental effort required to achieve proper performance. High mental workload is associated with high mental effort (17). When job demands increase, effort has to be mobilized in order to maintain the performance levels, which is associated with physiological and psychological costs (12).

The current study findings demonstrated a significant inverse relationship between frustration and work ability. Frustration refers to stress, anxiety, and discourage while doing a task (39). A study showed that frustration was most directly linked to constant heavy workloads (44). It should be noted that most of the study participants paid particular attention to stress and anxiety aspects of frustration, which is in agreement with the studies carried out by Kumasiro in oil industry (23) and by Habibi *et al.* (10) in petrochemical industry. Research has shown that stress-related symptoms could be predicting factors in assessing the individuals' work ability (32).

Limitations

This study had some limitations. Firstly, the cross-sectional design of the study did not allow actual causative conclusions to be made. Secondly, use of self-report measures could result in deception, denial, or recall biases. Finally, mental workload was measured using subjective methods, while the use of objective measures could lead to more conclusive results.

Conclusions

The findings of the present study indicated that mental workload was high and work ability was good in the control room operators. Indeed, increment in mental workload was associated with decrement in work ability. Moreover, mental demand, temporal demand, effort, and frustration were recognized to influence work ability. Thus, identifying and optimizing the factors affecting mental workload and work ability in control room operators should be considered in priority in any interventional program.

No potential conflict of interest relevant to this article was reported by the authors

References

1. Abdolalizadeh M, Arastoo A, Ghsemzadeh R, et al: The psychometric properties of an Iranian translation of the Work Ability Index (WAI) questionnaire. J Occup Rehabil 2012; 22: 401-408
2. Ahonen G, Bjurström L, Hussi T, Räsänen K: Economic effectiveness of the maintenance and promotion of work ability. Maintenance of Work Ability-Research and As-

sessment: Summaries Bilbao: Ministry of Social Affairs and Health, Finnish Institute of Occupational Health 2002: 33-44
3. Brešić J, Kneževič B, Miloševič M, et al: Stress and work ability in oil industry workers. Archives of Industrial Hygiene and Toxicology 2007; 58: 399-405
4. Brooke E, Goodall J, Handrus M, Mawren D: Applying workability in the Australian residential aged care context. Australas J Ageing 2013; 32: 130-134
5. Cinaz B, Arnrich B, Marca R, Tröster G: Monitoring of mental workload levels during an everyday life office-work scenario. Pers Ubiquitous Comput 2013; 17: 229-239
6. Felton EA, Williams JC, Vanderheiden GC, Radwin RG: Mental workload during brain–computer interface training. Ergonomics 2012; 55: 526-537
7. Gaba DM, Lee T: Measuring the Workload of the Anesthesiologist. Anesth Analg 1990; 71:3 54-361
8. Galy E, Cariou M, Mélan C: What is the relationship between mental workload factors and cognitive load types? Int J Psychophysiol 2012; 83: 269-275
9. González-Muñoz EL, Gutiérrez-Martínez RE: Contribution of mental workload to job stress in industrial workers. Work (Reading, Mass) 2007; 28: 355-361
10. Habibi E, Dehghan H, Safari S, et al: Effects of work-related stress on work ability index among refinery workers. Journal of education and health promotion 2014; 3: 18
11. Habibi E, Gharib S, Mohammadfam I, Rismanchian M: Human Error Assessment And Management Among Isfahan Oil Refinery Control Room Operators By Sherpa Technique. Int J Env Health Eng 2013; 2: 25
12. Hakanen JJ, Bakker AB, Schaufeli WB: Burnout and work engagement among teachers. J Sch Psychol 2006; 43: 495-513
13. Hansen CD, Andersen JH: Going ill to work–What personal circumstances, attitudes and work-related factors are associated with sickness presenteeism? Soc Sci Med 2008; 67: 956-964
14. Harris D, Stanton NA, Marshall A, et al: Using SHERPA to predict design-induced error on the flight deck. Aerosp Sci Technol 2005; 9: 525-532
15. Hart SG, Staveland LE: Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Advances in psychology 1988; 52: 139-183
16. Hoboubi N, Choobineh A, Ghanavati FK, et al: The impact of job stress and job satisfaction on workforce productivity in an Iranian petrochemical industry. Safety and health at work 2017; 8: 67-71
17. Hogervorst MA, Brouwer A-M, van Erp JB: Combining and comparing EEG, peripheral physiology and eye-related measures for the assessment of mental workload. Front Neurosci 2014; 8: 322
18. Hwang S-L, Yau Y-J, Lin Y-T, et al: Predicting work performance in nuclear power plants. Saf sci 2008; 46: 1115-1124
19. Ilmarinen J: Work ability - a comprehensive concept for occupational health research and prevention. Scand J Work Environ Health 2009:1-5
20. Ilmarinen J: The ageing workforce - challenges for occupational health. Occupational Medicine 2006; 56: 362-364
21. Kleinbaum DG, Kupper LL, Morgenstern H: Epidemiologic research: principles and quantitative methods: John Wiley & Sons; 1982
22. Kum S, Furush M, Iwasaki H: Investigation on the factors of VTS operators' mental workload: case of Turkish operators. International Journal on Marine Navigation and Safety of Sea Transportation 2007; 1(2)
23. Kumasiro M (editor):The improvement of stress moods and the increase in negative emotions toward work have a major impact on declines in WAI scores: The first WAI research in Japan. 4 th ICOH Conference on Ageing and Work Krakow: Jagiellonian Univ; 2002
24. Lin CJ, Yenn T-C, Jou Y-T, et al: Analyzing the staffing and workload in the main control room of the advanced nuclear power plant from the human information processing perspective. Saf Sci 2013; 57: 161-168
25. Loft S, Sanderson P, Neal A, Mooij M: Modeling and predicting mental workload in en route air traffic control: Critical review and broader implications. Human Factors: The Journal of the Human Factors and Ergonomics Society 2007; 49: 376-399
26. Marras WS, Karwowski W: Fundamentals and assessment tools for occupational ergonomics: CRC Press; 2006
27. Mazloumi A, Kazemi Z, Saraji JN, et al: Assessment workload and investigate relationship with fatigue in among driving force of traction railway republic of islamic Iran. Journal of Health and Safety at Work 2012; 2: 1-8
28. Mazloumi A, Rostamabadi A, Saraji GN, Foroushani AR: Work Ability Index (WAI) and its association with psychosocial factors in one of the petrochemical industries in Iran. J Occup Health 2012; 54: 112-118
29. Mohammadi M, Mazloumi A, Zeraati H: Designing questionnaire of assessing mental workload and determine its validity and reliability among ICUs nurses in one of the TUMS's hospitals. Journal of School of Public Health and Institute of Public Health Research 2013; 11: 87-96
30. Moore LJ, Wilson MR, McGrath JS, et al: Surgeons' display reduced mental effort and workload while performing robotically assisted surgical tasks, when compared to conventional laparoscopy. Surg endosc 2015; 29: 2553-2560

31. Moray N: Mental workload since 1979. International reviews of ergonomics 1988; 2: 123-150
32. Pohjonen T: Perceived work ability of home care workers in relation to individual and work-related factors in different age groups. Occupational Medicine 2001; 51: 209-217
33. Pranjić N, Maleš-Bilić L, Beganlić A, Mustajbegović J: Mobbing, stress, and work ability index among physicians in Bosnia and Herzegovina: survey study. Croatian medical journal 2006; 47: 750-758
34. Ryu K, Myung R: Evaluation of mental workload with a combined measure based on physiological indices during a dual task of tracking and mental arithmetic. Int J Ind Ergon 2005; 35: 991-1009
35. Safari S, Mohammadi H, Kazemi M: Evaluation Mental Work Load in Nursing Critical Care Unit with National Aeronautics and Space Administration Task Load Index (NASA-TLX). J Health Sys Res 2013; 9: 613-619
36. Safari S, Akbari J, Kazemi M, et al: Personnel's health surveillance at work: Effect of age, body mass index, and shift work on mental workload and work ability index. J Environ Public Health 2013; 2013
37. Schumacher S, Kleinmann M, Melchers KG: Job requirements for control room jobs in nuclear power plants. Saf Sci 2011; 49: 394-405
38. Sjögren-Rönkä T, Ojanen MT, Leskinen EK,et al: Physical and psychosocial prerequisites of functioning in relation to work ability and general subjective well-being among office workers. Scand J Work Environ Health 2002: 184-190
39. Stanton NA, Hedge A, Brookhuis K, et al: Handbook of human factors and ergonomics methods: CRC Press; 2004
40. Tuomi K, Huuhtanen P, Nykyri E, Ilmarinen J: Promotion of work ability, the quality of work and retirement. Occupational Medicine 2001; 51: 318-24
41. Tuomi K, Vanhala S, Nykyri E, Janhonen M: Organizational practices, work demands and the well-being of employees: a follow-up study in the metal industry and retail trade. Occupational Medicine 2004; 54: 115-121
42. van den Berg TI, Alavinia SM, Bredt FJ, et al: The influence of psychosocial factors at work and life style on health and work ability among professional workers. Int Arch Occup Environ Health 2008; 81: 1029-1036
43. Weinger MB, Vredenburgh AG, Schumann CM, et al: Quantitative description of the workload associated with airway management procedures. J Clin Anesth 2000; 12: 273-282
44. Whinghter LJ, Cunningham CJ, Wang M, Burnfield JL: The moderating role of goal orientation in the workload-frustration relationship. J Occup Health Psychol 2008; 13: 283
45. Wilkinson J, Lucas D: Better alarm handling—a practical application of human factors. Measurement and control 2002; 35: 52-54
46. Xiao Y, Li W, Ren Q, et al: [Effects of mental workload on work ability in primary and secondary school teachers]. Zhonghua lao dong wei sheng zhi ye bing za zhi= Zhonghua laodong weisheng zhiyebing zazhi= Chinese journal of industrial hygiene and occupational diseases 2015; 33:93-96
47. Yeow JA, Ng PK, Tan KS, et al: Effects of stress, repetition, fatigue and work environment on human error in manufacturing industries. J Appl Sci 2014; 14: 3464-3471
48. ZarraNezhad A, Jabbari M, Keshavarzi M:. Identification of the Human Errors in Control Room Operators by Application of HEIST Method (Case Study in Oil Company). Iran Occupational Health 2013; 10: 11-23

ACKNOWLEDGMENTS: *This article was extracted from the thesis written by Mrs. Fatemeh Kamari Ghanavati, MSc student of Occupational Health Engineering and financially supported by Shiraz University of Medical Sciences (grant No. 93-6976). The authors would like to thank Ms. A. Keivanshekouh at the Research Improvement Center of Shiraz University of Medical Sciences for improving the use of English in the manuscript. They are also grateful for the study participants who kindly allocated their time to the research.*