ELSEVIER

Applied Ergonomics 35 (2004) 233–241

APPLIED ERGONOMICS

www.elsevier.com/locate/apergo

Structural stability and reliability of the Swedish occupational fatigue inventory among Chinese VDT workers

Ada W.S. Leung[a], Chetwyn C.H. Chan[a,*], Jufang He[b]

[a] *Ergonomics and Human Performance Laboratory, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*

[b] *Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*

Received 17 May 2002; accepted 25 February 2004

Abstract

The aim of the present study was to test the structural stability and reliability of the Swedish occupational fatigue inventory (SOFI) for use in a group of Chinese visual display terminal (VDT) workers. A qualified translator was recruited to translate the Chinese version of the SOFI (SOFI-C). The content validity was established with 12 bilingual practitioners and seven professional experts. The translated SOFI was administered to 104 sedentary workers on two occasions with an interval of 60 min. Most of them were female (80.8%) and they had a mean age of 34.5 years. Fifty-one percent of them reported using a VDT for 4 h or more at work. Exploratory factor analysis revealed a five-factor solution, which was comparable to the original latent factors. Cronbach's alpha for the five-factor scales was between 0.88 and 0.95. The test–retest reliability was satisfactory with intra-class correlations ranging from 0.69 to 0.83. The workers who used a VDT for 4 h or more had significantly higher SOFI scores than those who used one for less than 4 h ($p = 0.007$–0.046). The results indicated that the SOFI-C was valid and reliable for measuring fatigue among Chinese sedentary workers. The satisfactory structural stability suggested that cultural influences on the construct of fatigue were not strong. Its characteristics of discrimination of the sedentary workers who had high VDT exposure suggested that the SOFI-C would be a useful instrument for prevention and intervention programs designed for work-related injuries in the workplace.

Keywords: Perceived fatigue; Measurement; Validity

1. Introduction

Fatigue is a common phenomenon for all workers, regardless of the type of occupation and cultural influences. A classic review by Bartley and Chute (1947) showed that fatigue is at least directly perceived, personal, and cumulative; arises from underlying conflicts; and may arise and disappear very suddenly. It is defined as the manifestation of a decrement of performance; that is, deterioration in performance as a result of having worked for a considerable length of time (Okogbaa et al., 1994). In occupational work, fatigue is related to the work task being performed and is exaggerated with a specific task demand being imposed on a person (Ahsberg, 2000). It is a gradual and accumulative process and can be briefly divided into mental and physical aspects. Mental fatigue is accompanied by a sense of weariness, reduced alertness, and reduced mental performance, whereas physical fatigue is accompanied by the reduction of performance in the muscular system.

The distinction between the physical and mental aspects of fatigue is found in the different neurophysiological interactions within the body. Previous studies have shown that the phenomenon is related to the suppression of the reciprocal feedback mechanisms between the cortex, the reticular activating system, and the hypothalamus (Adriaan et al., 1994; Roscoe, 1992). The interplay between the cortical and subcortical systems results in the manifestation of different fatigue symptoms such as sleepiness and deprived motivation (Kandel et al., 2000). In contrast, physical fatigue is primarily localized at the neuromuscular junction (Chaffin, 1973). It is induced when muscles engage in a

*Corresponding author. Tel.: +852-2766-6727; fax: +852-2330-8656.

E-mail address: rschchan@polyu.edu.hk (C.C.H. Chan).

0003-6870/$ - see front matter
doi:10.1016/j.apergo.2004.02.004

contractional state, which is aggravated by increased musculoskeletal exertion. In response to the increasing load intensity, the muscle fibers are engaged in the order of type I, type IIA, and finally type IIB (Bove and Lowenthal, 1983). As the skeletal muscle fibers are repeatedly stimulated, the tension developed by the fiber eventually decreases despite the continuous stimulation and resulting muscle fatigue. Similar to mental fatigue, physical fatigue is a subjective sensation of discomfort at specific places in the muscular structure which successively progresses to a dull and burning point, finally making muscle activity impossible (Oberg et al., 1994). The different neurophysiological mechanisms underlying mental and physical fatigue indicate that it is necessary to conduct their measurements separately. Furthermore, the measurement of fatigue has both an objective and a subjective component.

The objective measures of fatigue are largely made in relation to the physiological parameters, whereas subjective measures deal with self-perceived feelings (Hankins and Wilson, 1998). The physiological parameters include electrocardiography (ECG), electromyography (EMG), and electroencephalography (EEG) (Hankins and Wilson, 1998; Okogbaa et al., 1994; Schellekens et al., 2000; Waterink and Van Boxtel, 1994). For instance, mental fatigue can be associated with an increase in heart rate variability at the 0.1 Hz component, and an increase in both the slow (theta and alpha) and fast (beta) waveband EEG activities. Physical fatigue manifests itself in the changes in latency and amplitude of signals elicited from muscle contractions. Subjective measures are commonly in the form of rating scales such as the Likert fatigue scale and Borg's Category Rating Scale (CR 10-scale) (Borg, 1970, 1982, 1990; Borg and Hellstrom, 1987; Guyatt et al., 1987). The former has no line joining the rating categories and may have up to seven categories for rating (Guyatt et al., 1987). The latter is a physical exertion loading to category scale which assesses muscle fatigue in a high load situation (Oberg et al., 1994). Apart from these, the visual analogue scale (VAS) is also used in which marking on the 100 mm line (anchored by "no fatigue at all" at the left side of the scale and by "complete exhaustion" at the right side) indicates the severity of the fatigue sensation (Brunier and Graydon, 1996; Dixon and Bird, 1981; Sriwatanakul et al., 1983). The VAS was found to be useful for assessing muscle fatigue that extends to a low load situation (Leung et al., 1999) and is sensitive when it comes to reflecting different subjective feelings (Aun et al., 1986; Gift, 1989; Lee et al., 1991). Nevertheless, all of these subjective instruments measure the intensity of the perceived fatigue but not its quality.

Fatigue, as indicated above, is a common phenomenon in the workplace. Previous studies have shown that occupations requiring strong physical demands, such as those of firemen and manual workers, have a significantly high correlation to physical fatigue (Ahsberg, 2000; Ahsberg and Gamberale, 1998). In contrast, people who work at night and those who engage in intense mental work suffer to a great extent from mental fatigue (Ahsberg et al., 1997, 2000a, b). With sedentary work, fatigue is mostly mental since such work requires prolonged vigilance and mental activity. To a lesser extent, workers also report physical fatigue due to the prolonged use of a computer display screen and assumption of a sitting posture. Common symptoms reported by workers are feelings of tiredness, reduced motivation, and increased boredom (Finkelman, 1994; Rodahl, 1989). In view of the diversity and complexity of its measurement, a comprehensive instrument, which taps on workers' subjective feelings, is relevant for assessing fatigue at work.

The Swedish occupational fatigue inventory (SOFI) was developed for measuring work-related perceived fatigue (Ahsberg et al., 1997). It consists of 25 expressions which are categorized into five latent subscales. They are: lack of energy (LE), physical exertion (PE), physical discomfort (PD), lack of motivation (LM), and sleepiness (SL). Each subscale is defined by the content of the five expressions (Ahsberg et al., 1997) (details are given in Appendix A). Ahsberg et al. (1997) revealed particularly strong correlations between the LE subscale and the other four subscales, suggesting that it was an underlying dimension of fatigue. The PE and the PD subscales are considered as the physical factors, while the LM and the SL subscales are considered as the mental factors (Ahsberg et al., 1997). The validity of the SOFI was revealed in previous experimental and work situation studies (Ahsberg et al., 2000a, b). The five-factor structure of the SOFI was also demonstrated by relating the changes in the physiological parameters associated with fatigue, such as EEG and EMG measurements, with the SOFI scores.

The present study aimed to translate the English version of the SOFI into Chinese and then establish the psychometric properties of the translated version using a group of Chinese sedentary workers. The evidence collected for the Chinese version included content- and structural-related validity, and test–retest reliability. Translating the SOFI and applying it to a Chinese population involves the assumption that the subjective evaluation of fatigue is universal in nature (Kandel et al., 2000). This assumption was based on the premise that the fatigue mechanism is neuropsychological in nature. Cross-cultural issues, such as the equivalence of using different languages for writing the fatigue expressions, were dealt with in the content-related validity. The plausible differences involved in using the Likert scale to rate the fatigue expressions were explored in the contrast group comparison and the test–retest reliability. It was believed that the results of this study would contribute to the adaptation of the English version of the SOFI for the Chinese language. With an increasing number of workers engaged in sedentary work, such as data entry and computer operation in banking and telecommunications industries, the maintenance of workers' health is becoming more important. This is particularly so as China has undergone a rapid growth of industrial development and more emphasis has been placed on occupational health. A valid instrument would enable the establishment of baselines for the study of workload and work design, and prevention and intervention strategies for work-related injuries for the occupational group. The validation of the SOFI would also inform the cross-cultural perspective of the phenomenon of fatigue among workers.

2. Development of the Chinese version of the SOFI

The development process involved translation and an expert panel review. A qualified translator holding a bachelor's degree in translation was recruited to translate the SOFI into the Chinese version. An ethnocentric approach was used to guide the translation (Crocker and Algina, 1986). An expert panel consisting of 12 bilingual practitioners with a mean age of 25.8 years (SD = 2.7) was formed to evaluate the equivalence and clarity of the translation. They were all rehabilitation practitioners working in clinical settings such as hospitals with 2.0 years (SD = 1.1) of work experience. A questionnaire addressing the fluency and semantic equivalence of the test was designed to guide the evaluation process. The panel members were instructed to complete the questionnaire by assigning ratings on a five-point Likert scale: excellent (5), very good (4), good (3), fair (2), and poor (1). The panel members were encouraged to provide written comments to justify their evaluations. Consensus was reached through discussion among the members to further improve the Chinese version. To ensure the SOFI-C could be easily understood by the general public, 10 sedentary workers with a mean age of 29.7 years (SD = 2.8) were asked to provide comments on the extent to which the Chinese SOFI was understood. They were office workers with 7.9 years (SD = 2.1) of work experience.

The mode of the ratings assigned by the panel members on the equivalence of the SOFI-C was computed. Twenty-one out of the 25 items had a mode rating of four or above, indicating a good to excellent equivalence of the item translation. The four items considered to be at most fairly equivalent (mode ratings $\leqslant 3$) were: "Lack of concern", "Falling asleep", "Spent", and "Drained". The members commented that the Chinese translation of these items seemed either inappropriate or difficult to understand. After the discussion among the members, consensus was reached on the modifications to be made to the Chinese translation. The review by the 10 worker members indicated that the test instructions and all the 25 items were easy to understand.

The SOFI was then subject to a content evaluation on its relevance and representativeness with respect to its five content factors describing fatigue. A review panel composed of four rehabilitation professionals and three sedentary workers was formed. The rehabilitation professionals were all occupational therapists with a mean age of 29.3 years (SD = 2.3) and at least 4 years of work experience in physical rehabilitation. The sedentary workers were frequent computer operators with a mean age of 35.7 years (SD = 7.4) who worked for at least 6 h a day. All the members were invited to attend a panel meeting and evaluate the extent to which the 25 SOFI items were relevant to Chinese culture in describing the feeling of fatigue. Similarly, the questionnaires were collected and consensus was reached to guide the modification of the translated SOFI-C.

The five latent factors of the SOFI were all reported as relevant and adequately representing the assessment of occupational fatigue. All the mode ratings were four or above, and the percentages of agreement ranged from 71% to 86%. All 25 items were agreed to be relevant and representative in regard to the evaluation of occupational fatigue under their corresponding subscales. Similarly, all the mode ratings were four or above, and the percentage of agreement ranged from 71% to 100%. As a result, no items were adjusted and no additional items were added to the SOFI-C. The final version of the SOFI-C is shown in Appendix B.

3. Method

3.1. Participants

A total of 104 sedentary workers working in a hospital setting were recruited to participate in the field test. At the time of recruitment, the hospital safety committee launched a program for prevention of work-related musculoskeletal disorders. The names of the potential participants were given to the research team. The participants were contacted via mail prior to the seminar. The mail contained a description pamphlet which introduced the purpose of the study and invited them to participate in the data collection during the seminar. A consent form was also sent to the participants together with the pamphlet. The participants were requested to sign the consent form and bring it with them when they attended the seminar. All the participants worked in different clerical offices and support units and were predominantly sedentary office workers. They all worked 8-h shifts during office hours. The total

Table 1
Demographic characteristics of the participants ($N = 104$)

Variables	Number
Age (years)	
Mean	34.5
SD	7.4
Gender (%)	
Male	19.2
Female	80.8

working hours were 44 per week. The demographic characteristics of the participants are summarized in Table 1. A majority of them were female (80.8%). Their mean age was 34.5 years (SD = 7.4). Nearly all the participants (97.1%) were educated up to form 5 or above. About one-third (30.8%) of them had completed university courses. A few of them (3.8%) reported that they had received training in occupational safety. About half of them (49.0%) reported using a visual display terminal (VDT) for less than 4 h a day, and 51% reported using one from 4 to 8 h a day. At the time of data collection, they were participating in the action seminar, which lasted for 1 h.

3.2. Procedure

All the participants gathered around 3:30 pm prior to the commencement of the action seminar, which was held in one of the conference rooms of the hospital. The participants who volunteered to join the study handed in their signed consent forms at the reception counter. Each of them received an instruction sheet, a demographic form, a musculoskeletal discomfort evaluation form, and two copies of the SOFI-C—versions A and B. They were given 10 min to read the instruction sheet and complete the demographic form, the discomfort evaluation form, and the SOFI-C (version A). The demographic form contained items on age, gender, education level, work experience, and average number of hours spent using a VDT at work. The musculoskeletal discomfort evaluation form used a dichotomous yes–no format to solicit the participants' reports on discomfort in eight body parts, namely head, eyes, neck, shoulders, elbows, wrists, lower back, and legs. The SOFI-C (version A) contained the 25 expression items, which were arranged in the same sequence as in the original SOFI. The participants were instructed to assign ratings on each item that described their feelings of fatigue at that moment. The completed demographic form and the SOFI-C (version A) were collected from all the participants before the seminar began. The ratings on version A reflected the fatigue level of the participants after working for an entire day.

The seminar lasted for 60 min and covered the signs and symptoms of work-related injuries, and their prevention and interventions. The two speakers were an orthopedic specialist and an ergonomics practitioner. After the seminar, the participants were instructed to complete the SOFI-C (version B), which had been distributed to them during the previous test. The ratings on version B reflected the fatigue level of the participants after attending the seminar which was used to test the test–retest reliability of SOFI-C. Version B was different from version A in that the 25 expression items were rearranged in a randomized order. This was to reduce the impact brought about by the memory effect of the participants due to their prior completion of the questionnaire an hour before. Version B took about 5–10 min to complete. The participants handed in the completed questionnaire before they left the conference room.

3.3. Data analysis

The scores on the SOFI-C (version A) were analyzed to obtain evidence on the structural-related validity and internal consistency (Chan and Lee, 1999). Exploratory factor analysis was conducted using the principal component extraction and varimax rotation to explore its subscale structure (Crocker and Algina, 1986). Cronbach's alpha was used to estimate the internal consistency of the SOFI-C (Crocker and Algina, 1986). Intra-class correlations (ICCs) were computed on the results obtained from versions A and B, which estimated the test–retest reliability (Portney and Watkins, 2000). Analysis of variance (both univariate and multivariate) was used to examine the effects of duration of VDT usage on SOFI-C subscale scores. Comparisons were conducted by first grouping the participants according to the average time which they used VDT: i.e. 0–<2, 2–<4, 4–<6, 6–<8, and ⩾8 h. This was followed by re-grouping the participants into the low (<4 h) and high (⩾4 h) usage groups. The latter would allow the comparisons of the results obtained in this study with those reported by Fahrbach and Chapman (1990). All the statistical analysis was performed using the statistical package SPSS and the significance level was set at $p < 0.05$.

4. Results

The scores on the SOFI-C (version A) are summarized in Table 2. The subscale score on "LE" was the highest, followed by "SL" and "LM". The lowest two were "PD" and "PE". The majority of the participants reported discomfort in the eyes (81.0%), neck (73.3%), and shoulders (61.9%) (Table 3). The frequency of discomfort being reported in the other body parts was comparatively less (between 10.5% and 26.7%).

Table 2
Mean (SD) of participants' scores on the SOFI-C ($N = 104$)

SOFI-C subscales	Beginning of seminar (version A)	End of seminar (version B)
Sleepiness	3.07 (2.03)	3.31 (2.25)
Physical discomfort	2.90 (1.93)	2.76 (1.92)
Lack of motivation	2.94 (2.05)	2.78 (2.26)
Lack of energy	3.52 (2.27)	3.45 (2.27)
Physical exertion	2.26 (1.79)	1.98 (1.74)

Table 3
Body discomfort reported by the participants ($N = 104$)

Body parts	Response "yes" (%)
Head	23.8
Eyes	81.0
Neck	73.3
Shoulders	61.9
Elbows	12.4
Wrists	26.7
Lower back	15.2
Legs	10.5

Exploratory factor analysis indicated a five-factor structure, which accounted for 78.16% of the total variance (Table 4). Interpretable results were obtained when orthogonal rotation using the varimax technique was conducted. The five factors extracted appeared to coincide with those in the original instrument. They were: Factor 1, "SL"; Factor 2, "PD"; Factor 3, "LM"; Factor 4, "LE"; and Factor 5, "PE". The initial analysis indicated that only 16 items (those with asterisks) were primarily loaded onto the original five subscales, which gave the highest factor loadings. As a result, Factors 1 and 2 showed the best fit to the original SL and PD subscales. However, the item "Lazy", which loaded the highest on Factor 3 (LM), showed a secondary loading on Factor 1. The same pattern was revealed for the item "Numbness", which loaded on Factor 3 followed by Factor 2. If the criterion of $\geqslant 0.3$ factor loading was adopted to make a decision on the significance of the item-to-subscale relationship (Nunnally and Bernstein, 1994), 23 out of the 25 items in the SOFI-C were found to load onto the respective factors, which was similar to the original SOFI subscales. The only two items which did not have a factor loading above the decision rule were "Listless" (0.23) under LM and "Palpitation" (0.28) under PE.

The Cronbach's alpha values estimated based on the SOFI-C (version A) results are presented in Table 5. The alpha values ranged from a high of 0.95 for the LE subscale to a low of 0.88 for the PD subscale, indicating satisfactory internal consistency for the SOFI-C subscales (Nunnally and Bernstein, 1994). The test–retest reliability indices of the SOFI subscales estimated by ICC were between 0.69 and 0.83 (SEM = 0.64–0.21). If

Table 4
Factor loadings of the 25 items of the SOFI-C

SOFI-C item	SOFI Factors				
	1	2	3	4	5
Sleepiness					
Yawning	**0.85***	0.11	0.09	0.13	0.27
Sleepy	**0.82***	0.32	0.13	0.16	0.09
Falling asleep	**0.81***	0.20	0.27	0.25	0.06
Drowsy	**0.68***	0.24	0.17	0.37	0.29
Lazy	**0.44**	0.06	0.76*	0.05	0.19
Physical discomfort					
Tense muscle	0.10	**0.82***	0.15	0.26	0.13
Aching	0.33	**0.76***	0.22	−0.12	0.26
Stiff joints	0.21	**0.63***	0.35	0.25	0.22
Hurting	0.14	**0.50***	0.46	0.38	0.35
Numbness	0.20	**0.39**	0.58*	−0.05	0.33
Lack of motivation					
Lack of concern	0.02	0.26	**0.77***	0.37	0.08
Indifferent	0.28	0.17	**0.63***	0.52	0.26
Listless	0.50	0.21	0.23	0.64*	0.23
Passive	0.44	0.15	**0.44**	0.57*	0.24
Uninterested	0.41	0.19	**0.30**	0.52*	0.44
Lack of energy					
Spent	0.33	0.44	0.25	**0.66***	0.21
Exhausted	0.22	0.57	0.17	**0.60***	0.32
Drained	0.47	0.45	0.28	**0.48***	0.34
Overworked	0.37	0.68*	0.14	**0.40**	0.19
Worn out	0.22	0.63*	0.36	**0.47**	0.00
Physical exertion					
Warm	0.14	0.15	0.35	0.24	**0.70***
Sweaty	0.37	0.29	0.18	0.17	**0.69***
Out of breath	0.20	0.33	0.53	0.28	**0.55***
Palpitation	0.06	0.35	0.65*	0.28	0.28
Breathing heavily	0.30	0.28	0.50*	0.27	**0.46**

Remarks: Method: principal component extraction with orthogonal varimax rotation.
Items with * represent loading primarily on the five factors.
Items with bold type indicate loading onto their original subscale in the forced five-factor solution with factor loadings ($\geqslant 0.3$).

Table 5
Internal consistency of SOFI-C subscales and their test–retest reliability indices ($N = 104$)

SOFI-C subscales	α	ICC* (95% C.I.)	S.E.M.
Sleepiness	0.90	0.69 (0.57–0.78)	0.64
Physical discomfort	0.88	0.83 (0.76–0.88)	0.23
Lack of motivation	0.90	0.77 (0.68–0.84)	0.21
Lack of energy	0.95	0.77 (0.68–0.84)	0.51
Physical exertion	0.89	0.80 (0.72–0.86)	0.59

Remarks: The Cronbach's alpha coefficients (α) are computed on the SOFI-C (version A).
The test–retest reliability coefficients are estimated using intra-class correlations (two-way mixed model).
S.E.M. = standard error of measurement of test–retest reliability indices.

the criterion of $\geqslant 0.75$ was adopted to indicate good reliability (Portney and Watkins, 2000), all of the SOFI-C subscales had satisfactory test–retest reliability indices except the SL subscale, which was moderate (ICC = 0.69, SEM = 0.64).

A review of the participants' SOFI-C subscale scores indicated that they scored the highest on the LE subscale and the lowest on the PE subscale (Table 6). The differences among the five subscale scores were statistically significant ($F(4, 524) = 5.22$, $p < 0.005$). A post hoc comparison adjusted by the Bonferroni method further showed that the participants had significantly higher scores on the SL and LE subscales ($p = 0.04$ and $p < 0.005$, respectively). The effect of duration of VDT usage on participants' fatigue ratings was tested by grouping the participants into five categories: i.e. 0–<2, 2–<4, 4–<6, 6–<8, and ⩾8 h. The SOFI-C subscale scores appeared to peak at the 4–<6 and ⩾8 h groups (Table 6). However, multivariate analysis of variance (MANOVA) did not reveal statistical significance in the differences among the five groups (Pillai's Bartlett trace: $F(20, 340) = 1.319$, $p = 0.162$). The participants were re-grouped into the low (<4 h) and high (⩾4 h) usage groups (Table 7). The SOFI-C scores of participants in the high usage group were found significantly higher than those in the low usage (Pillai's Bartlett trace: $F(5, 98) = 2.32$, $p = 0.049$). Univariate F-tests further indicated that the differences were in the PD ($F(1, 104) = 7.51$, $p = 0.007$), LE ($F(1, 104) = 6.45$, $p = 0.013$), and LM subscales ($F(1, 104) = 4.09$, $p = 0.046$).

5. Discussion

The results of this study indicate that the 25 SOFI expressions and its five-factor structure are largely relevant for measuring fatigue in the Chinese VDT users. The high content representativeness and fairly stable factorial structure suggest that the fatigue phenomenon associated with VDT work has little cultural bias. The findings also reveal that the Chinese version of the SOFI has satisfactory test–retest reliability. The five-factor SOFI scores were found to be useful in discriminating the workers who used a VDT for 4 h or more at work from those who used one for less than 4 h.

Previous literature reveals that fatigue is both a physiological and a perceptual process. For mental fatigue, the neurophysiological mechanism involves the interplay between higher cortical functioning such as alertness and vigilance, and subcortical activation such as general arousal (Grandjean, 1988; Rodahl, 1989). It results in a central effect on the mental function such as tiredness and sleepiness. For physical fatigue, the physiological mechanism primarily occurs at the neuromuscular junction, which inhibits muscle contraction. It has a localized effect on the physical function such as depleted muscle contraction. These mental and physical signals are elicited within the individual and are experienced by the individual. Such experiences are interpreted at the time individuals are requested to rate their fatigue state on the SOFI. Our findings did not reveal a strong cultural effect when the SOFI was translated into Chinese and rated by the Chinese participants. First, the expert panel members did not identify major problems with the relevance of the 25 SOFI expressions and the representativeness of the five-factor SOFI structure for measuring fatigue in the context of Chinese culture. Despite there being several studies that suggest the specificity of Chinese culture in regard to pain perception (Chung et al., 1999, 2000), the generalization of the results based on pain to the perception of fatigue seems to be limited. In general,

Table 6
Mean (SD) of SOFI-C subscale scores of participants in five VDT usage groups (average number of hours/workday)

SOFI-C subscales	0–<2 h ($n = 26$)	2–<4 h ($n = 24$)	4–<6 h ($n = 25$)	6–<8 h ($n = 19$)	⩾8 h ($n = 7$)
Sleepiness	3.28 (2.47)	4.05 (2.19)	4.40 (2.05)	3.64 (2.23)	4.69 (1.54)
Physical discomfort	2.85 (2.31)	3.13 (1.95)	4.24 (1.76)	3.83 (1.53)	4.60 (1.48)
Lack of motivation	2.56 (2.36)	3.70 (1.81)	4.53 (2.30)	3.51 (2.08)	4.11 (1.70)
Lack of energy	3.49 (2.44)	4.34 (2.63)	5.16 (2.13)	4.27 (2.04)	5.46 (1.90)
Physical exertion	2.60 (2.19)	2.90 (1.66)	3.54 (1.99)	2.67 (1.76)	3.79 (2.07)

Table 7
Mean (SD) of SOFI-C subscale scores between participants using a VDT for <4 h versus ⩾4 h a day

SOFI-C subscales	VDT<4 h ($n = 51$)	VDT⩾4 h ($n = 53$)	All participants ($N = 104$)
Sleepiness	2.89 (2.18)	3.24 (1.87)	3.07 (2.03)
Physical discomfort	2.38 (1.91)	3.38 (1.83)	2.90 (1.93)
Lack of motivation	2.53 (2.04)	3.34 (2.01)	2.94 (2.05)
Lack of energy	2.95 (2.30)	4.06 (2.12)	3.52 (2.27)
Physical exertion	1.99 (1.69)	2.51 (1.86)	2.26 (1.79)

the description of pain is complex and multi-dimensional in nature, and is largely influenced by language in its perception, interpretation, and expression (Chung et al., 2000; Kodiath and Kodiath, 1995). In contrast, fatigue is multi-faceted, but its factorial structure is fairly simple such as in the SOFI. The item descriptors use simple language, which place less demand on the interpretation and expression by the subjects. Second, the factorial structure of the SOFI-C was, to a large extent, comparable to the original SOFI developed by Ahsberg et al. (1997). The marginal findings in regard to a few of the Chinese expressions, which loaded differently from the original version, are probably attributable to the job nature of the subjects who participated in the field test, rather than to culture or language. For instance, the "Palpitation (*sum tiu kap chuk*)" item had a low factor loading on the PE subscale. The fact was that prolonged VDT work rarely led to physical exhaustion and hence the sensation of palpitation meant that the item carried a very small variance for the exploratory factor analysis. The loading of the "Listless (*mood ching da choi*)" item on the LE instead of the LM subscale may be due to the fact that the LE subscale is a more general description of fatigue for sedentary workers which tended to attract the less stable item.

Our findings demonstrate the usefulness of the SOFI profiles for reflecting the differences in job demands among VDT workers. Further analysis showed that the participants who used a VDT for 4 h or more a day scored significantly higher on the LE, LM, and PD subscales than those who used one for less than 4 h. The SOFI results for Chinese workers also concur with Fahrbach and Chapman (1990) who concluded that using a VDT for 4 h or more per day was a critical factor in the development of fatigue. The significant increase in the subscale scores based on the SOFI-C also match the results from the original instrument of Ahsberg et al. (1997). Ahsberg et al. further asserted that the three subscales were accounted for because of the maintenance of a high state of vigilance and prolonged sitting in a static posture. Besides the intensive cortical activation and hormonal stress which results in general tiredness and declined motivation (Kandel et al., 2000), the long period of static posture and keyboard operation triggered musculoskeletal discomfort such as numbness, muscle soreness, and joint stiffness (Siu et al., 1999; Vasseljen and Westgaard, 1997; Westgaard and Aaras, 1984). Likewise, workers who use a VDT for 4 h or more per day are potentially more vulnerable to occupational fatigue.

In this study, an attempt was made to group the participants into five usage groups according to the duration of using VDT at work. Variations in the SOFI-C subscale scores were observed across the different usage group. However, the differences were not large enough be statistically significant. Power analysis suggests that it may be due to the small sample size in two of the usage groups: i.e. 6–<8 h ($n = 19$) and $\geqslant$8 h ($n = 7$). Further studies are recommended to increase the sample size particularly for the high usage groups. It is important to note that, despite the study was carried out on the Chinese VDT workers in Hong Kong, the results may not be readily to be generalized to those who are in the mainland China. The workers in Hong Kong are likely to share a similar socio-cultural background and languages with those living in larger cities in the south of China. However, differences in socio-culture background, languages, and work pattern and schedule between workers in Hong Kong and those in the rest of China may prompt for further studies on the validity and generalization of the SOFI-C among the entire Chinese population.

The SOFI-C is found useful for quantifying and documenting work-related fatigue among Chinese workers. It may be used to detect fatigue—a risk factor of occupational injuries—among workers in the workplace. It could serve as a screening tool for identifying workers who are in a state of fatigue and have the potential to develop work-related problems such as repetitive strain injuries or stress. Early identification and immediate intervention are good strategies for preventing occupational injuries. The instrument can

Table 8

Subscale 1: Physical exertion	
	Items: Palpitation
	Sweaty
	Warm
	Out of breath
	Breathing heavily
Subscale 2: Physical discomfort	
	Items: Tense muscle
	Numbness
	Stiff joints
	Hurting
	Aching
Subscale 3: Lack of energy	
	Items: Worn out
	Exhausted
	Spent
	Drained
	Overworked
Subscale 4: Lack of motivation	
	Items: Lack of concern
	Listless
	Passive
	Indifferent
	Uninterested
Subscale 5: Sleepiness	
	Items: Lazy
	Falling asleep
	Drowsy
	Yawning
	Sleepy

also be used as an outcome measure to support the effectiveness of interventions for work redesign and workload modification.

6. Conclusion

This study indicates that the SOFI-C is a valid and reliable tool for measuring fatigue among Chinese VDT workers in Hong Kong. The Chinese translation of the original SOFI does not seem to carry significant cultural or language effects. The test content and five-factor structure were preserved, which support its content-related validity and structural stability. The internal consistency and test–retest reliability of the Chinese version were also satisfactory. Furthermore, the SOFI-C was found to discriminate between workers who had prolonged VDT usage and those who had less. Its development enhances the quantification of work-related fatigue, and the prevention and intervention of occupational-related injuries.

Acknowledgements

The authors would like to thank Ms Flora Ko for her assistance on organizing the seminars for data collection. This project was supported by the research grant of Occupational Safety and Health Council, Hong Kong.

Appendix A

The items in each subscale are listed below (extracted from the article: Ahsberg et al., 1997) (see Table 8).

Appendix B

(see Table 9).

Table 9
Swedish Occupational Fatigue Inventory.

Think of how you feel now. To what extent do the expressions below describe how you feel? For every expression, answer spontaneously, and mark the number that corresponds to how you feel right now. The numbers vary between 0 (not at all) and 10 (to a very high degree)

瑞典職業疲勞評估表

中文版
試想想現在你的疲勞感覺。以下的詞語在什麼程度上正確地形容你現在的感覺？請隨你自己的意願圈出相當於你現在感覺的程度的數字。數字由 0 (程度極少) 至 10 (程度極大) 排列。

	程度極少									程度極大
	0	1	2	3	4	5	6	7	8	9	10
心跳急速 Palpitation	0	1	2	3	4	5	6	7	8	9	10
不感關注 Lack of concern	0	1	2	3	4	5	6	7	8	9	10
懶惰 Lazy	0	1	2	3	4	5	6	7	8	9	10
筋疲力竭 Worn out	0	1	2	3	4	5	6	7	8	9	10
肌肉繃緊 Tense muscle	0	1	2	3	4	5	6	7	8	9	10
麻痺 Numbness	0	1	2	3	4	5	6	7	8	9	10
冒汗 Sweaty	0	1	2	3	4	5	6	7	8	9	10
精力耗盡 Exhausted	0	1	2	3	4	5	6	7	8	9	10
沒精打彩 Listless	0	1	2	3	4	5	6	7	8	9	10
打瞌睡 Falling asleep	0	1	2	3	4	5	6	7	8	9	10
體力耗盡 Spent	0	1	2	3	4	5	6	7	8	9	10
昏昏欲睡 Drowsy	0	1	2	3	4	5	6	7	8	9	10
消極被動 Passive	0	1	2	3	4	5	6	7	8	9	10
關節僵硬 Stiff joints	0	1	2	3	4	5	6	7	8	9	10
發暖 Warm	0	1	2	3	4	5	6	7	8	9	10
漠不關心 Indifferent	0	1	2	3	4	5	6	7	8	9	10
痛苦 Hurting	0	1	2	3	4	5	6	7	8	9	10
喘不過氣 Out of breath	0	1	2	3	4	5	6	7	8	9	10
打呵欠 Yawning	0	1	2	3	4	5	6	7	8	9	10
體力衰竭 Drained	0	1	2	3	4	5	6	7	8	9	10
渴睡 Sleepy	0	1	2	3	4	5	6	7	8	9	10
操勞過度 Overworked	0	1	2	3	4	5	6	7	8	9	10
疼痛 Aching	0	1	2	3	4	5	6	7	8	9	10
呼吸沉重 Breathing heavily	0	1	2	3	4	5	6	7	8	9	10
枯燥乏味 Uninterested	0	1	2	3	4	5	6	7	8	9	10

Note: Translated from the Swedish occupational fatigue inventory (SOFI); extracted from Ahsberg et al. (2000b).

References

Adriaan, H., Van Zomeren, A.H., Brouwer, W.H., 1994. Anatomy and physiology of attention. In: Adriaan, H., Van Zomeren, A.H., Brouwer, W.H. (Eds.), Clinical Neuropsychology of Attention. Oxford University Press, New York, pp. 39–62.

Ahsberg, E., 2000. Dimensions of fatigue in different working populations. Scand. J. Psychol. 41, 231–241.

Ahsberg, E., Gamberale, F., 1998. Perceived fatigue during physical work: an experimental evaluation of a fatigue inventory. Int. J. Ind. Ergon. 21, 1117–1131.

Ahsberg, E., Gamberale, F., Kjellberg, A., 1997. Perceived quality of fatigue during different occupational tasks: development of a questionnaire. Int. J. Ind. Ergon. 20, 121–135.

Ahsberg, E., Gamberale, F., Gustafsson, K., 2000a. Perceived fatigue after mental work: an experimental evaluation of a fatigue inventory. Ergonomics 43, 252–268.

Ahsberg, E., Kecklund, G., Akerstedt, T., Gamberale, F., 2000b. Shiftwork and different dimensions of fatigue. Int. J. Ind. Ergon. 26, 457–465.

Aun, C., Lam, Y.M., Collett, B., 1986. Evaluation of the use of visual analogue scale in Chinese patients. Pain 25, 215–221.

Bartley, S., Chute, E. (Eds.), 1947. Fatigue and Impairment in Man. McGraw-Hill, New York.

Borg, G., 1970. Perceived exertion as an indicator of somatic stress. Scand. J. Rehabil. Med. 2 (3), 92–98.

Borg, G., 1982. A category scale with ration properties for intermodal and interindividual comparisons. In: Geissler, H.G., Petzold, P. (Eds.), Psychophysical judgement and the process of perception. VEB Deutscher Verlag der Wissenschaften, Berlin, pp. 25–34.

Borg, G., 1990. Psychophysiological scaling with applications in physical work and the perception of exertion. Scand. J. Work Environ. Health 16, 55–58.

Borg, G., Hellstrom, A., 1987. Perception and psychophysics with ergonomic applications. In: Lundgern, N., Luthman, G., Elgstrand, K. (Eds.), Man at Work. Almqvist & Wiksell, Stockholm, pp. 315–355.

Bove, A.A., Lowenthal, D.T. (Eds.), 1983. Exercise Medicine: Physical Principle and Clinical Applications. Academic Press, New York, pp. 3–17.

Brunier, G., Graydon, J., 1996. A comparison of two methods of measuring fatigue in patients on chronic haemodialysis: visual analogue versus Likert scale. Int. J. Nurs. Stud. 33 (3), 338–348.

Chaffin, D.B., 1973. Localized muscle fatigue-definition and measurement. J. Occup. Med. 15, 346–354.

Chan, C.C.H., Lee, T.M.C., 1999. Clinical evaluation: from validation to practice. In: Anchor, K.N., Felicetti, T.C. (Eds.), Disability Analysis in Practice: Framework for an Interdisciplinary Science. Kendall/Hunt, Dubuque, pp. 357–376 (Chapter 20).

Chung, J.W., Wong, C.H., Yang, J.C., Wong, T.K., 1999. The construction of a pain intensity verbal rating scale in Chinese. Acta Anaesthesiologica Sinica 37 (2), 65–71.

Chung, J.W.Y., Wong, T.K.S., Yang, J.C.S., 2000. The Len model: assessment of cancer pain in a Chinese context. Cancer Nurs. 23 (6), 454–461.

Crocker, L., Algina, J. (Eds.), 1986. Introduction to Classical and Modern Test Theory. Holt, Rinehart and Winston, Orlando.

Dixon, J.S., Bird, H.A., 1981. Reproducibility along a 10 cm vertical visual analog scale. Ann. Rheum. Dis. 40 (1), 87–89.

Fahrbach, P.A., Chapman, L.J., 1990. VDT work duration and musculoskeletal discomfort. American Association of Occupational Health Nurses Journal 38 (1), 32–36.

Finkelman, J.M., 1994. A large database study of the factors associated with work-related fatigue. Hum. Factors 36, 232–243.

Gift, A.G., 1989. Visual analogue scales: measurement of subjective phenomena. Nurs. Res. 38 (5), 286–288.

Grandjean, E., 1988. Fatigue. In: Grandjean, E. (Ed.), Fitting the Task to the Man: a Textbook of Occupational Ergonomics. Taylor & Francis, Philadelphia, pp. 156–168.

Guyatt, G.H., Townsend, M., Berman, L.B., Keller, J.L., 1987. A comparison of Likert and visual analogue scales for measuring change in function. J. Chronic Dis. 40 (12), 1129–1133.

Hankins, T.C., Wilson, G.F., 1998. A comparison of heart rate, eye activity, EEG and subjective measures of pilot mental workload during flight. Aviat. Space Environ. Med. 69 (4), 360–367.

Kandel, E.R., Schwartz, J.H., Jessell, T.M. (Eds.), 2000. Principles of Neural Science, 4th Edition. McGraw-Hill, Columbia.

Kodiath, M.F., Kodiath, A., 1995. A comparative study of patients who experience chronic malignant pain in India and the United States. Cancer Nurs. 18 (3), 189–196.

Lee, K.A., Hicks, G., Nino-Murcis, G., 1991. Validity and reliability of a scale to assess fatigue. Psychiatry Res. 36, 291–298.

Leung, A.W.S., Lee, A.H.S., Lam, K.W.H., 1999. Visual analogue scale as measure of musculoskeletal fatigue. Unpublished Master of Sciences Dissertation, The Hong Kong Polytechnic University, Hong Kong.

Nunnally, J.C., Bernstein, I.H. (Eds.), 1994. Psychometric Theory, 3rd Edition. McGraw-Hill, New York.

Oberg, T., Sandsjo, L., Kadefors, R., 1994. Subjective and objective evaluation of shoulder muscle fatigue. Ergonomics 37 (8), 1323–1333.

Okogbaa, O.G., Shell, R.L., Filipusic, D., 1994. On the investigation of the neurophysiological correlates of knowledge worker mental fatigue using the EEG signal. Appl. Ergon. 25 (6), 355–365.

Portney, L.G., Watkins, M.P., 2000. Foundations of Clinical Research: Application to Practice. Prentice-Hall, Englewood Cliffs, NJ.

Rodahl, K., 1989. The Physiology of Work. Taylor & Francis, London.

Roscoe, A.H., 1992. Assessing pilot workload: why measure heart rate, HRV and respiration? Biol. Psychol. 34, 259–287.

Schellekens, J.M.H., Sijtman, G.J., Vegter, E., Meijman, T.F., 2000. Immediate and delayed after-effects of long lasting mentally demanding work. Biol. Psychol. 53, 37–56.

Siu, Z.K.F., Chan, C.C.H., Wong, L.T.L., Hung, L.K., 1999. Work-related psychological factors and musculoskeletal discomfort among VDT workers. In: Proceedings of the Work Stress and Health '99: Organization of Work in a Global Economy. American Psychological Association and National Institute for Occupational Safety and Health, Baltimore, 1999, p. 207.

Sriwatanakul, K., Kelvie, W., Lasagna, L., Calimlim, J.F., Weis, O.F., Metha, G., 1983. Studies with the different types of visual analog scales for the measurement of pain. Clin. Pharmacol. Ther. 34 (2), 234–239.

Vasseljen, O., Westgaard, R.H., 1997. Arm and trunk posture during work in relation to shoulder and neck pain and trapezius activity. Clin. Biomech. 12 (1), 22–31.

Waterink, W., Van Boxtel, A., 1994. Facial and jaw-elevator EMG activity in relation to changes in performance level during a sustained information processing task. Biol. Psychol. 37, 183–198.

Westgaard, R.H., Aaras, A., 1984. Postural muscle strain as a causal factor in the development of musculo-skeletal illness. Appl. Ergon. 15 (3), 162–174.