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PORTUGUESE VERSION OF THE SWEDISH OCCUPATIONAL FATIGUE INVENTORY (SOFI) AMONG ASSEMBLY WORKERS: CULTURAL ADAPTATION, RELIABILITY AND VALIDITY

JOANA SANTOS[1,2,3], CARLOS CARVALHAIS[1], CATARINA RAMOS[4], TIAGO COELHO[5], PEDRO RIBEIRO ROCHA MONTEIRO[2], and MÁRIO A.P. VAZ[3]

[1] Polytechnic Institute of Porto, Porto, Portugal
Scientific Area of Environmental Health and Research Centre on Health and Environment (CISA), School of Health (ESS – P.Porto)
[2] Polytechnic Institute of Porto, Porto, Portugal
Activity and Human Movement Study Center (CEMAH), School of Health (ESS – P.Porto)
[3] University of Porto, Porto, Portugal
Porto Biomechanics Laboratory, Institute of Mechanical Engineering and Industrial Management (LABIOMEP/INEGI), Faculty of Engineering
[4] ISPA – University Institute, Lisbon, Portugal
William James Center for Research
[5] Polytechnic Institute of Porto, Porto, Portugal
Scientific Area of Occupational Therapy, School of Health (ESS – P.Porto)

Abstract
Objectives: Reliable and valid instruments are essential for understanding fatigue in occupational settings. This study analyzed the psychometric properties of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI). **Material and Methods:** A cross-sectional study was conducted with 218 workers from an automotive industry involved in assembly tasks for fabrication of mechanical cables. Convergent and discriminant validity, internal consistency reliability and confirmatory factor analysis were performed. **Results:** Results showed adequate fit to data, yielding a 20-item, 5-factor structure (all intercorrelated): Chi^2/df (ratio Chi^2 and degrees of freedom) = 2.530, confirmatory fit index (CFI) = 0.919, goodness of fit index (GFI) = 0.845, root mean square error of approximation (RMSEA) = 0.084. The SOFI presented an adequate internal consistency, with the sub-scales and total scale presenting good reliability values (Cronbach's α values from 0.742 to 0.903 and 0.943 respectively). **Conclusions:** Findings suggest that the Portuguese version of the SOFI may be a useful tool to assess fatigue and prevent work-related injuries. In future research, other instruments should be used as an external criterion to correlate with the SOFI dimensions. Int J Occup Med Environ Health 2017;30(3):407–417

Key words:
Reliability, Confirmatory factor analysis, Validity, Cultural adaptation, Perceived fatigue, Swedish Occupational Fatigue Inventory

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Corresponding author: J. Santos, Polytechnic Institute of Porto, Scientific Area of Environmental Health, School of Health (ESS – P.Porto), Rua Dr. António Bernardino De Almeida 400, 4200-072 Porto, Portugal (e-mail: jds@ess.ipp.pt).

INTRODUCTION

The term fatigue has been used consistently in the literature to describe a state of tiredness that is clinically significant and pathological in nature [1]. It is usually defined as a condition of feeling very tired, weary or sleepy resulting from insufficient sleep, prolonged mental or physical work, extended periods of stress or anxiety. However, a new whole definition of fatigue has been proposed by Phillips recently [2], "Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional nature of the condition depends on the form, dynamics and context of exertion. The context of exertion is described by the value and meaning of performance to an individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions. The fatigue results in changes in strategies or resource use such as original levels of mental processing or physical activity that are maintained or reduced."

Fatigue is probably the most common symptom of illness affecting sufferers of both acute and chronic conditions [3]. It results from the interaction between mental and physical factors, which are very difficult to evaluate separately [4], and it is usually associated with boring or repetitive work-related tasks. At the broadest level, occupational fatigue has been linked to an imbalance between the intensity and duration and timing of work with recovery time [5]. Indeed, acute fatigue may occur when there is inadequate time to rest and recover from a work period. It tends to disappear after taking some rest [6]. On the other hand, cumulative (chronic) fatigue occurs when there is insufficient recovery from acute fatigue over time [7].

Fatigued workers may find themselves working closer to their maximal capabilities, putting themselves at greater risk for the development of not only musculoskeletal injuries, but also psychosocial disorders [8]. Several studies have identified that fatigue is a contributing factor for accidents, injuries and death in a wide range of settings, because people with fatigue symptoms are less likely to produce safe performance and actions [9,10]. Consequently, in order to avoid chronic fatigue, it is important to develop effective strategies or measures to prevent [11] and detect acute fatigue and to recover from it [12,13].

In general, fatigue is not well understood and it is typically measured as a multidimensional phenomenon with subjective and performance based indicators. The objective measures of fatigue are largely related to its physiological parameters, while subjective indicators report self-perceived feelings [14]. Within occupational settings, the need to minimize assessment time and to maximize compliance by ensuring that measures are simple, easy and valid for the work, influences the selection of measures that are used and the measurement regime [15]. Assessing perceived fatigue (measured through the use of self-report measures) seems to be adequate to measure fatigue. There are several instruments developed to assess fatigue for clinical use, and a few – for occupational context. The Swedish Occupational Fatigue Inventory (SOFI), is an example of a self-report instrument developed for occupational assessment of fatigue, which has been used in both contexts over the last fifteen years [16–24]. Considering that there is no Portuguese version of the SOFI, the aim of this study is to present the translation and cultural adaptation process of the SOFI into Portuguese and to examine the psychometric properties of the Portuguese version among assembly workers.

MATERIAL AND METHODS

Sample

A cross-sectional study was conducted at a multinational corporation devoted to the production of mechanical cables for the automotive industry. The Portuguese version of the SOFI was applied to 290 workers of the production section at the end of their shifts. Each of them received an instruction sheet, a demographic form,

the SOFI as well as the consent form. Two hundred and eighteen workers delivered the SOFI fulfilled (the response rate of 75.17%). The company works 24 h a day and working hours are distributed over three shifts (the morning shift: 6 a.m. to 2 p.m.; afternoon shift: 2 p.m. to 10 p.m.; night shift: 10 p.m. to 6 a.m.). The dominant gender of the sample was female (92.7%). The average age was 36.20±9.37 years old (18 years old – the youngest and 61 years old – the oldest). The shift distribution was 56.8% (the afternoon shift), 23% (the morning shift) and 20.1% (the night shift). The company's management board approved this study, and all participants gave their written informed consent.

Instrument

The initial version of the SOFI consisted of 25 expressions which represented 5 dimensions/sub-scales: Lack of energy; Physical exertion; Physical discomfort; Lack of motivation and Sleepiness [25]. Each dimension was defined by the content of 5 expressions related to physiological, cognitive, motor and emotional responses [26]. An 11-grade response scale was used, where only the 2 extreme values had a verbal label, 0 "not at all" and 10 "to a very high degree" [25]. However, after testing the validity of all the dimensions of the SOFI [25,27–30], the final version maintained the 5 dimensions but with 20 expressions (4 items per dimension), namely: Lack of energy (worn out, spent, drained, overworked), Physical exertion (palpitations, sweaty, out of breath, breathing heavily), Physical discomfort (tense muscles, numbness, stiff joints, aching), Lack of motivation (lack of concern, passive, indifferent, uninterested) and sleepiness (falling asleep, drowsy, yawning, sleepy). The internal consistency for each factor of this version varied between 0.81–0.92. During this process, the 11-grade response scale was replaced by a 7-grade response scale, where the extreme values were verbally labeled, 0 "not at all" and 6 "to a very high degree" [30]. The Swedish Occupational Fatigue Inventory was already translated and validated into the Spanish and Chinese languages [14,26], with good psychometric characteristics. In this work the final version of the original SOFI (5 dimensions; 20 items; 7-grade response scale) was studied.

Translation and cultural adaptation process

This process was carried out according to the guidelines of the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) [31], beginning with the permission to use the SOFI to the main author of the instrument. Two authors of this research, who are fluent in English, and an English translator, translated it from English into Portuguese. At this stage, the clarification of some expressions was discussed with the original instrument's author. After the forward translations had been analyzed, a single forward translation was achieved. Two professional English translators carried out the back translation. The back translation results were reviewed, and a harmonization of all new versions and source version was performed in order to detect and deal with any discrepancies that could have arisen between different language versions, ensuring conceptual equivalence [31,32]. To assess the level of comprehensibility of the translation, a cognitive debriefing was made, involving a pretest with 22 participants. In addition, a multidisciplinary panel (3 experts in the field of psychology, ergonomics and occupational health research) was asked to proofread and provide the opinion on the face and content validity of the preliminary version. Although the draft was shown to be acceptable in the preliminary pilot survey, slight changes were made to the original expressions.

Data analysis

Descriptive techniques were used for analyzing and characterizing the subjects. The confirmatory factor analysis (CFA) of the Portuguese version to verify the 5-dimensional structure proposed by Åhsberg [30] was carried out. In this sense the following goodness of

fit indices were used: the ratio Chi^2 and degrees of freedom (Chi^2/df), confirmatory fit index (CFI), Tucker Lewis index (TLI), goodness of fit index (GFI), Parsimony Goodness-of-Fit Index (PGFI) and root mean square error of approximation (RMSEA). The model's adjustment was considered good for the CFI, GFI and TLI values above 0.90, the RMSEA values between 0.06 and 0.10, and the PGFI values above 0.60 [33]. To examine whether each dimension of the observed variables was strongly related to each other, the convergent validity was evaluated. The Average Variance Extracted (AVE) and the Composite Reliability (CR) were estimated [33,34]. Values of the AVE > 0.50 and CR > 0.70 are indicative of convergent validity and adequate construct reliability [33].

Whether the items that reflect a dimension are not correlated with another dimension, i.e., if the AVE for each dimension is greater than the average variation shared between each factor and other factors in the model is determined by the assessment of discriminant validity [33]. The discriminant validity was estimated according to the proposal submitted by Fornell and Larcker [34] who claimed that for 2 factors i and j, if the AVE_i and AVE_j > squared correlation between factors i and j (ϱ_{ij}^2)), an evidence of discriminant validity existed. Factorial validity was assessed by the analysis of factorial weights of the items (λ). If all the items of a dimension have $\lambda \geq 0.5$, it is assumed that the dimension has factorial validity; if $\lambda^2 \geq 0.25$ is an indicator of an appropriate individual reliability of the item [33]. Internal consistency of each dimension and for total scale were estimated through Cronbach's Alpha (α). Alpha values of 0.70–0.95 were regarded as satisfactory [35]. The analysis was performed using the AMOS® version 22.0 software integrated with IBM SPSS™ version 22.0 (SPSS Inc., USA), at a significance level of 5%.

RESULTS

In the first step, the nested model proposed by Åhsberg [30] was tested. In general the results indicated a poor fit to the data. Root mean square error of approximation (RMSEA) was above 0.10, the CFI, GFI and TLI were lower than 0.90, which indicates an unacceptable adjustment to the model (Table 1).

In the second step, a model with the same 20 observed variables but evenly distributed on 5 latent variables (all assumed to be intercorrelated) was tested. The results shown in the Table 1 revealed that this model was better compared to the nested model. Therefore, the modification indices (MI) were inspected. They showed high error covariances between the error terms of item 12 and item 20 (MI = 19.944) and also between the error terms of item 14 and item 16 (MI = 24.430). The proposed final model includes the correlation between those errors as shown in the Figure 1. An improvement in most of the goodness-of-fit statistics and an overall good model fit: Chi^2/df = 2.530, CFI = 0.919, GFI = 0.845, RMSEA = 0.084 were found. The Table 1 summarizes the results from the confirmatory analyses of the SOFI models tested.

Table 1. Summary of results from confirmatory analyses of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) [30]

Model	Chi^2/df	RMSEA	CFI	TLI	GFI	PGFI
Nested model 20 items	3.258	0.102	0.867	0.848	0.792	0.626
20 items	2.626	0.087	0.909	0.890	0.833	0.626
20 items (final model)	2.530	0.084	0.919	0.901	0.845	0.623

Chi^2/df – ratio Chi^2 and degrees of freedom; RMSEA – root mean square error of approximation; CFI – confirmatory fit index; TLI – Tucker Lewis index; GFI – goodness of fit index; PGFI – Parsimony Goodness-of-Fit Index.

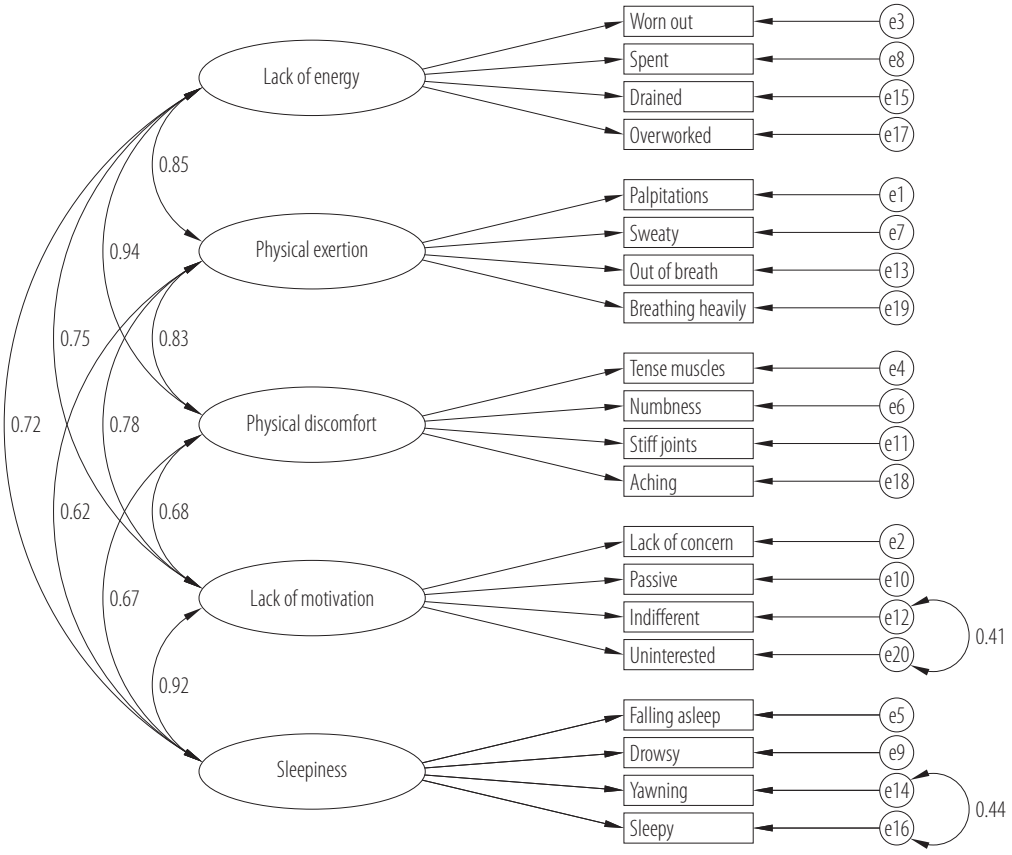

Fig. 1. Confirmatory factor analysis of the Portuguese version of Swedish Occupational Fatigue Inventory (SOFI) [30]

The reported fatigue during work is presented in the Table 2 by means of standard deviations and kurtosis indices of each item of the SOFI. Lack of energy was the sub-scale, the items of which had the highest scores followed by Physical discomfort, Physical exertion, Lack of motivation and Sleepiness.

Correlations between factors are shown in the Figure 1. The values were high and varied between 0.62–0.92. The Table 3 shows factor weights ($\lambda > 0.50$) and adequate individual reliability ($\lambda^2 > 0.25$) for all items. Factor weights of the items ranged between 0.601–0.770 for Physical exertion, 0.692–0.853 for Physical discomfort, 0.606–0.810 for Lack of motivation, 0.776–0.902 for Lack of energy and 0.634–0.818 for Sleepiness.

The results obtained regarding internal consistency, convergent and discriminant validity are shown in the Table 4. Convergent validity (AVE > 0.50 and CR > 0.7 in all dimensions, respectively), discriminant validity ($\varrho^2 <$ AVE in all dimensions) and internal consistency ($\alpha > 0.7$ in all dimensions) were found to be adequate. Average variance extracted values ranged between 1.25 (Physical exertion) to 4.32 (Lack of energy) showing that the items of a dimension converged well with each other. Composite reliability values ranged between 0.832 (Physical exertion) to 0.945 (Lack of energy) and Cronbach's α values ranged from a high of 0.903 (Lack of energy) to a low of 0.742 (Physical exertion), indicating satisfactory internal consistency for all dimensions. Cronbach's α for the total scale of the Portuguese version of the SOFI was also high (0.943). All of the correlations among the 5 factors were highly significant (0.38–0.88). In addition, the higher correlation was found between Lack of energy and Physical discomfort.

Table 2. Ratings of fatigue on the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) [30]

Sub-scale and item	M	SD	Kurtosis
Lack of energy			
worn out	2.54	1.810	–0.787
spent	2.91	1.996	–1.208
drained	3.15	1.950	–1.115
overworked	2.69	1.978	–1.168
Physical exertion			
palpitations	1.81	1.685	–0.767
sweaty	3.12	2.110	–1.253
out of breath	0.95	1.446	2.714
breathing heavily	1.56	1.688	0.220
Physical discomfort			
tense muscles	2.91	1.948	–1.136
numbness	2.02	2.007	–0.873
stiff joints	2.33	2.003	–1.012
aching	2.58	1.993	–1.197
Lack of motivation			
lack of concern	1.39	1.519	–0.215
passive	1.47	1.650	0.384
indifferent	1.14	1.639	1.343
uninterested	0.92	1.484	3.026
Sleepiness			
falling asleep	1.66	1.864	–0.229
drowsy	1.51	1.620	0.850
yawning	1.62	1.595	0.373
sleepy	1.73	1.741	–0.149

M – mean; SD – standard deviation.

Table 3. Factorial weights (λ) of the items of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) [30] distributed by sub-scale

Sub-scale and item	λ	λ^2
Physical exertion		
palpitations	0.601	0.361
sweaty	0.613	0.376
out of breath	0.635	0.403
breathing heavily	0.770	0.593

Table 3. Factorial weights (λ) of the items of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) [30] distributed by sub-scale – cont.

Sub-scale and item	λ	λ^2
Physical discomfort		
tense muscles	0.834	0.696
numbness	0.692	0.479
stiff joints	0.750	0.563
aching	0.853	0.728
Lack of motivation		
lack of concern	0.648	0.420
passive	0.810	0.656
indifferent	0.606	0.367
uninterested	0.679	0.461
Lack of energy		
worn out	0.800	0.640
spent	0.902	0.814
drained	0.871	0.759
overworked	0.776	0.602
Sleepiness		
falling asleep	0.758	0.575
drowsy	0.818	0.669
yawning	0.634	0.402
sleepy	0.769	0.591

Table 4. Internal consistency, convergent and discriminant validity of the Portuguese version of the Swedish Occupational Fatigue Inventory (SOFI) [30]

Sub-scale	AVE	CR	α	ϱ^2				
				Physical exertion	Physical discomfort	Lack of motivation	Lack of energy	Sleepiness
Physical exertion	1.25	0.832	0.742	1.000	–	–	–	–
Physical discomfort	2.83	0.918	0.868	0.684	1.000	–	–	–
Lack of motivation	1.51	0.857	0.817	0.608	0.457	1.000	–	–
Lack of energy	4.32	0.945	0.903	0.719	0.882	0.556	1.000	–
Sleepiness	2.19	0.897	0.848	0.383	0.449	0.852	0.514	1.000
Total scale	–	–	0.943	–	–	–	–	–

AVE – average variance extracted; CR – composite reliability; α – Cronbach's alpha; ϱ^2 – squared correlation between factors.

DISCUSSION

The main purpose of this study has been to examine the psychometric properties of a Portuguese version of the SOFI on a sample of assembly workers. Highly repetitive movements, standardized and short-cycle tasks with different levels of complexity, typically characterize assembly production systems. The Swedish Occupational Fatigue Inventory has been used for assessing perceived fatigue in repetitive work by other researchers [23,36]. Physical and mental aspects of fatigue assessed by the SOFI are included in the recent "whole definition" of fatigue proposed by Phillips [2].

Overall, the results provide preliminary evidence that the adapted version of the SOFI is a useful and psychometrically sound instrument to assess fatigue among Portuguese workers. The strength of this structure certified the importance of the 5 dimensions in defining the construct fatigue.

The results of the confirmatory factorial analysis of the theoretical 5-factor model (the nested model) did not provide satisfactory fit indexes. According to this model, Lack of energy was defined as a general latent factor, which represented much of the common variance in all items. Interestingly, the results of the current study supported a 5 factor model, with 20 variables distributed on 5 latent factors, in contrast to previous studies [26,37]. Accordingly, Byström et al. [37] found that the relationship between appraised psychological workload and musculoskeletal symptoms were not mediated by Lack of energy, suggesting that this factor was not sufficient to describe the role of fatigue in the development of musculoskeletal symptoms.

All items had high loadings that suggested a stronger factor contribution to those variables. Data regarding factorial weights and the good fit of the model confirmed factorial validity of the instrument and justified the decision not to remove items of the scale. Additionally, it was found that all dimensions of the instrument had convergent and discriminant validity.

The Portuguese version of the SOFI demonstrated a good internal consistency. The reliability coefficient (Cronbach's α) was quite similar to those obtained in the Chinese version (with 25 items) [14] and higher than in the Spanish version (with 15 items) [26]. High Cronbach's α coefficients for the 5 sub-scales and the SOFI total scale indicate that the items of the Portuguese version of the SOFI are highly homogeneous for the sample under the study. The results regarding the CR suggest the same pattern.

The rigorous process of translation and cultural adaptation and the study of several psychometric properties have been the main strengths of this research. However, the main limitation of this study is related to sampling technique. Indeed, as subjects were recruited by convenience, generalizability of the results to other samples of workers has been limited. Furthermore, the fact that the sample is mainly comprised of women may have cause some bias.

CONCLUSIONS

In conclusion, results suggest that the Portuguese version of the SOFI is a psychometrically robust self-report measure of perceived fatigue in a sample of assembly workers. Consequently, the SOFI seems to be a valuable and user-friendly tool for ergonomists, occupational health practitioners and researchers to assess fatigue in industrial settings, allowing a greater involvement of workers in organizational decisions, namely related to individual job design, in order to improve workers' quality of life and health.

However, as the study of the reliability and validity of an instrument is a continuous process of analysis, further research is needed considering that the psychometric evidence presented in this study does not guarantee total invariance inter-contexts. Since this paper may be seen as a preliminary research on psychometric properties of the Portuguese version of the SOFI, future longitudinal research is needed to examine the test–retest reliability of the Portuguese version and more studies about its validity should be developed, in particular, studies regarding

the invariance in various occupational groups and using external criterion measures.

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