European Journal of Oncology Nursing 36 (2018) 62–67

Contents lists available at ScienceDirect

European Journal of Oncology Nursing

journal homepage: www.elsevier.com/locate/ejon

Fatigue in cancer patients: Development and validation of a short form of the Multidimensional Fatigue Inventory (MFI-10)

Louise Baussard[a,b,*], Marion Carayol[a,b], Bertrand Porro[a], Fanny Baguet[a,b], Florence Cousson-Gelie[a,b]

[a] Laboratory Epsylon EA4556 Dynamics of Human Abilities and Health Behaviors, University of Montpellier 3, Montpellier, France
[b] Epidaure, Prevention Department, Montpellier Cancer Institute, Montpellier, France

ARTICLE INFO

Keywords:
Cancer
Oncology
Exploratory confirmatory factor analysis
Fatigue measurement
Assessment

ABSTRACT

Purpose: The MFI was developed in 1995 to assess fatigue as a multidimensional concept. This questionnaire has been widely translated and used; however, its multidimensional structure has not been consistent across studies. In addition there is a need for short questionnaires in the clinical context. Therefore, we aim to develop a MFI-short version which is easy-to-use for the patient, quick for the clinician, with solid psychometric properties.
Methods: We examined three MFI-20 validated versions and tested their structure, by leading a CFA on 422 cancer patients to evaluate their psychometric qualities (Study 1). Then, we conducted both EFA and CFA by deleting all reversed items. We assumed that 10 items were sufficient to conserve a good explanation of the data and a multidimensional structure (Study 2).
Results: Study 1 revealed that there is no consensus about the structure of the three MFI versions tested and CFA showed inadequate fit (*RMSEA* > .10; *CFI* < .9). Those three versions showed an inadequate fit with regard to expected fit indices. In study 2, the multidimensional structure was confirmed with only ten items. The best model gave a three-factor solution with a $\chi^2 = 67.130$, a *RMSEA* = .072 (95% CI [.048-.096]) and a *CFI* equal to .97.
Conclusions: The MFI short-form maintains good psychometric quality. This new questionnaire is adapted to cancer populations, and may be useful for clinicians to screen their patients' fatigue. Further validations of this MFI-short form are warranted to confirm its psychometric properties in other populations.

1. Introduction

Currently, the number of people living with cancer is increasing. Based on Globocan (2012) estimates (a database from the International Agency for Research on Cancer), about 14,1 million new cancer cases occurred in 2012 worldwide (Torre et al., 2015). Three cancers accounted for more than four million cases in 2012: 1,676,600 for breast cancer, 1,360,600 for colorectal cancer for both genders, and 385,700 cases for rare cancers such as Non-Hodgkin's Lymphomas (Torre et al., 2015). Patients living with cancer or being treated for cancer declare a wide range of side effects, due to the disease itself, to the treatments and to their internal emotional state (Wagland et al., 2015). One of the most common symptoms reported by cancer patients is Cancer-Related-Fatigue (CRF) (Berger et al., 2015; Prue et al., 2006). Compared with the fatigue experienced by healthy individuals, CRF is less likely to be relieved by rest, is more distressing, and differs in daily evolution profiles (Glaus et al., 1996). The wide range of prevalence of CRF from 60% to 99% depends on the measurement tools and stage of disease (Lawrence et al., 2004). Developing a consensus about the definition of CRF took a long time and now the majority of studies understand fatigue as multidimensional (Ahlberg et al., 2003; Minton and Stone, 2009). CRF concerns many areas, including physical state, emotional state, and cognitive aspects.

In clinical practice, it is recommended to assess CRF systematically rather than waiting until patients spontaneously complain about this symptom (Buss et al., 2014). Therefore, appropriate measurement instruments should be used to detect CRF. Fillion et al. (2003) highlighted three methodological concerns regarding fatigue assessment (Fillion et al., 2003). First, CRF is different and more severe than non-cancer related fatigue, so questionnaires must be developed for cancer patients specifically. Second, there is a need for consensus about the CRF definition, considering CRF as subjective and multidimensional (physical, cognitive and emotional). The National Comprehensive Cancer Network (NCCN) provides a consensual definition of CRF: “a distressing

* Corresponding author. Epidaure-ICM Val d’Aurelle, Parc Euromedecine 208 Rue des Apothicaires, 34298, Montpellier Cedex 5, France.
E-mail address: louise.baussard@icm.unicancer.fr (L. Baussard).

https://doi.org/10.1016/j.ejon.2018.07.005
Received 20 March 2018; Received in revised form 12 July 2018; Accepted 15 July 2018

persistent subjective sense of physical, emotional, and/or cognitive tiredness or exhaustion related to cancer or cancer treatment that is not proportional to recent activity and that interferes with usual functioning" (NCCN National Comprehensive Cancer Network, 2017). Third, another recommendation is to adapt questionnaires to the population they target. Simple and short questionnaires are required, as health professionals lack time in care pathways Moreover, cancer patients are easily tired and this extreme fatigability causes a loss of autonomy. In summary, the recommendation is to develop questionnaires based on a consensual definition of CRF and specific to one population, with good psychometric qualities (Fillion et al., 2003).

Fillion et al. (2003) support their argument with a study from Meek et al. (2000) which described and compared four frequently used fatigue instruments: The Shortened Profile of Mood-fatigue subscale (POMS-sf) (Shacham, 1983), the Multidimensional Assessment of Fatigue (MAF) (Tack, 1991), the Lee Fatigue Scale (LFS) (Lee et al., 1991), and the Multidimensional Fatigue Inventory (MFI) (Smets et al., 1995). Among those, only the MFI addresses the aforementioned recommendations, and was developed originally for use with patients who have been diagnosed with cancer (Fillion et al., 2003; Meek et al., 2000).

The MFI was developed in 1995 by a team from the Netherlands (Smets et al., 1995), and among instruments rating CRF, the MFI has the theoretical advantage of encompassing all aspects of fatigue. Items were elaborated based on patients' interviews and literature review, to reflect five dimensions of fatigue: general fatigue, physical fatigue, mental fatigue, reduced activities and reduced motivation. The 20 items are sufficient to cover multidimensional fatigue. Many researchers have used this questionnaire in multiple pathologies, especially in the cancer population, but the different validated versions available attest that there is no consensus about the structure, and the number of dimensions or the rating (global score or dimension scores). Among the different versions of the MFI, some authors considered 5 dimensions, some 4 and some even 3 dimensions. A consensus does not exist. Therefore, a literature review of the MFI versions available worldwide in cancer patients was the first step of our study.

Table S1 a good three-dimensional structure presents all the steps developed by teams to validate the MFI or to make their transcultural validation. We found fifteen validation papers (Baptista et al., 2012; Buss et al., 2014; Chandel et al., 2015; Chilcot et al., 2017; Elbers et al., 2012; Fillion et al., 2003; Gentile et al., 2003; Hafezi et al., 2010; Lin et al., 2009; Lundh Hagelin et al., 2007; Munguía-Izquierdo et al., 2012; Schneider, 1998; Smets et al., 1995; Smets et al., 1996; Tian and Hong, 2012).

The first two studies concerned the initial version developed by Smets and collaborators (Smets et al., 1995, 1996). All further validations are based on the English version from Smets et al. (1996), consisting of 20 items and five dimensions: general fatigue, physical fatigue, mental fatigue, lack of motivation and activities reduction. In French, the MFI was validated by Gentile et al., in 2003. The translation is accurate and well-accepted by respondents, however the selected population was not cancer patients. They conducted an EFA with Principal Component Analysis (PCA) but did not include a Confirmatory Factor Analysis (CFA). The final structure was changed from five dimensions in the English version to four dimensions in the French one (Gentile et al., 2003). They did not remove any items. Two dimensions among the 5 (general and physical fatigue) were combined into one (physical fatigue).

Among the 15 validation studies, six did not include cancer patients (Chilcot et al., 2017; Elbers et al., 2012; Gentile et al., 2003; Hafezi et al., 2010; Lin et al., 2009; Munguía-Izquierdo et al., 2012). Among the nine studies that included cancer patients (Baptista et al., 2012; Buss et al., 2014; Chandel et al., 2015; Fillion et al., 2003; Lundh Hagelin et al., 2007; Schneider, 1998; Smets et al., 1995, 1996; Tian and Hong, 2012), only two conducted a complete psychometric analysis with both EFA and CFA (Buss et al., 2014; Fillion et al., 2003). One is a French Canadian version published by Fillon et al. (Fillion et al., 2003). Their MFI version resulted in four dimensions (as Gentile et al., 2003) with 15 items out of the initial 20 items. Some problems with the structure were noted in particular with item loadings: four items loaded on two different dimensions, and one item loaded on an unexpected dimension. These confusing findings were previously reported, suggesting that some methodological/psychometric improvement could be accomplished (Meek et al., 2000). The version proposed by Fillion et al. (2003) resulted in an MFI with 15 items and a four-factor model showing acceptable fit (Table 1 annexed). It is the only MFI version available in French that has been validated in a cancer patient population. The other one carried out by Buss et al. in Poland (Buss et al., 2014), included both EFA and CFA conducted in cancer patients. Their validation resulted in a three-dimension questionnaire (physical, mental and reduced motivation fatigue). This study showed good methodology. The authors deleted five items, as Fillion et al. (2003) did. The removed items are not the same between the two studies and all of them are reverse worded. In addition, the latest validation study published in 2017 demonstrated poor fit and a non-reliable factor model of the MFI-20 (Chilcot et al., 2017).

In order to go further, we wanted to question the MFI's structure. This questionnaire was constructed in the 1990s where much consideration was given to response bias. All the difficulties in developing a questionnaire were to prevent response styles. Indeed, among the 20 items of the MFI, ten were reversed (Smets et al., 1995). A recent paper published by Van Sonderen et al. explained the ineffectiveness of reverse wording in questionnaires (Van Sonderen et al., 2013). The authors first distinguished several types of response bias that are often confused in the literature (acquiescence, inattention, confusion), and then argued that reversing items is probably not a good way to address response bias. The results indicated that reversing a portion of the items is common practice, although there is no consensus that this is an effective strategy. In this literature review (Van Sonderen et al., 2013), the authors showed that (i) preventing response styles by reverse wording lowered questionnaires' validity; (ii) replacing the reversed items with non-reversed items improved the internal consistency; and (iii) the use of opposite items introduced noise, increasing the risk of measurement error. As an illustration regarding MFI, Van Sonderen et al. tested if reverse wording affects response bias in the MFI with data from 700 respondents with inflammatory bowel disease. Results indicated an adverse effect of reversed wording and showed that internal consistency was better with a positive scale or a negative scale only. Many developers of questionnaires have adopted the reversed wording strategy in order to avoid response bias, however Van Sonderen et al. found evidence that it does not decrease response bias (Van Sonderen et al., 2013). Reversing half of the items was reported as less precise and more inattentive, depending on the length of the questionnaire. Respondents might feel annoyed by a 20-item questionnaire which is rather redundant. As an example, an item such as "physically I feel I am in bad condition" is the reversed item of "physically I feel I am in an excellent condition". Considering this fact, we decided to test a short version of the MFI with only 10 items.

2. Method

This article presents two studies. The first study evaluates the psychometric properties of the MFI, by conducting a CFA on three versions of the MFI that differ by the number of items and/or number of dimensions. We decided to test our data with the original version by Smets et al., with Gentile's French version, because it is often used in French studies, and finally with Fillion's version, which is the only French validation available for cancer patients (Fillion et al., 2003; Gentile et al., 2003; Smets et al., 1995). These analyses were conducted to show fit indices associated to these MFI structures (respectively 5 dimensions, 4 dimensions, or 4 dimensions and 5 fewer items).

The aim of the second study was to develop a short version of the

MFI. As reversed items did not yield higher internal consistency (Van Sonderen et al., 2013), we removed the 10 MFI items with reverse wording. Then, we conducted both EFA and CFA on the resulting MFI-10 items to evaluate if 10 items are sufficient to conserve the multi-dimensional approach and good fit indices.

2.1. Population samples

Participants were selected from four different research projects. All four studies (Baussard et al., 2016; Carayol et al., 2013; Cousson-Gélie et al., 2013; Porro et al., 2016) received an investigation approval by an Ethics Committee and were approved through the number 2010-A00906-33 (sample 1), DR-2015-730 (sample 2), 2008-001506-16 (sample 3) and 2013-13-779 (sample 4). All participants were asked to sign a consent form. The combination of those four studies was performed with the intent to represent a wide range of cancer patients regarding cancer sites, treatments and fatigue levels. In all of the studies, fatigue assessment was performed by using the MFI-20. Sample 1 included women from the Adapted Physical Activity and Diet (APAD) randomized controlled trial and included patients with breast cancer (BC) who were eligible for 6 cycles of adjuvant chemotherapy (Carayol et al., 2013). Sample 2 involved metastatic colorectal cancer undergoing chemotherapy (Baussard et al., 2016). Sample 3 was an ancillary study to a randomized trial named Frail (Cousson-Gélie et al., 2013) that included patients with Non-Hodgkin's lymphomas. Finally, the last sample was 68 women diagnosed with BC (Porro et al., 2016). For all the samples, the MFI was administered at baseline and before starting a new treatment.

2.2. Statistical methods

Both EFA and CFA were performed using R software version 3.2.3. Several R software packages were used: psych (Revelle, 2014), stats (R Core Team, 2014) and lavaan (Rosseel, 2012). Parallel analysis, available within the nFactors package, was used to determine the number of factors to extract (Raiche, 2010). The recommended number of factors to extract is the number of original eigenvalues that are greater than the corresponding eigenvalues from the simulated data. Items were retained if their unique variance was $< .80$, their factor loading $> .40$ or cross-loadings $< .30$ on a second factor. Data were treated as ordered-categorical (Rhemtulla et al., 2012) for both EFA and CFA. The EFA extraction method was Maximum Likelihood followed by a Promax rotation (Kappa = 4).

According to the principles for reporting analyses using structural equation modelling, the estimated models were compared using the following goodness-of-fit statistics: chi-square statistic (χ^2), comparative fit index (CFI), Tucker–Lewis index (TLI), and root mean square error of approximation (RMSEA). A good fit is obtained with a low χ^2; CFI, GFI, and TLI values $\geq .90$ (Maroco, 2010); and is further confirmed by RMSEA values less than .08 (Barrett, 2007).

When conducting a CFA, one should not be governed by the fit indices of the model alone (Farrell and Rudd, 2009). There are other factors to consider such as the factor loadings and the discriminant validity. Thus, we analyzed the factor loadings (λ) of the observed variables and their squares, which provided the amount of variance in the observed variable that the underlying construct is able to explain. Normally, it is expected that all items of the factor present values of $\lambda = .50$. We calculated the average variance extracted (AVE) of each latent construct to assess convergent validity. Convergent validity is the extent to which indicators (items) of a specific construct share a high proportion of variance, and is indicated by values of AVE $> .50$ (Maroco, 2010). Discriminant validity was established if the Maximum Shared Variance (MSV) and the Average Shared Squared Variance (ASV) were both lower than the AVE for all the constructs (Hair et al., 1998; Henseler et al., 2015). To assess scale reliability, we used both Cronbach's alpha and composite reliability, which provides a much less biased estimate of reliability than Cronbach's alpha and is more appropriate for multidimentional scales (Maroco, 2010).

Table 1
Description of the four samples.

	Sample 1 *Breast Cancer* N = 143 34 (%)	Sample 2 *Colorectal Cancer* N = 168 40 (%)	Sample 3 *Non-Hodgkin's Lymphoma* N = 43 10 (%)	Sample 4 *Breast Cancer* N = 68 16 (%)
Sex				
Male	0	96	21	0
Female	143	72	22	68
Age in years *mean (sd)*	51.6 (10.1)	64.3 (11.06)	81.5 (4.49)	46.97 (6.92)
Education Level				
No qualifications	23	17	13	–
Secondary level	29	70	18	–
high school	31	29	5	–
≥ 2 years at University	60	52	4	–
Marital status				
Single/divorced/ widowed	18	41	18	12
Married/w. partner	125	127	22	56
Occupational status				
Unemployed/ Medical leave	12	62	0	3
Retired	36	90	43	0
Working (partial/ full time)	95	16	0	65
Stage of cancer				
In situ	0	0	0	10
I	62	10	0	36
II	62	35	6	19
III	18	91	11	3
IV	0	32	30	0

3. Results

3.1. Study 1: psychometric qualities of three different MFI versions

3.1.1. Descriptive statistic

Patients' characteristics are summarized in Table 1. A total of 422 MFI-20 questionnaires were completed, with 72% women respondents. BC patients were the youngest, whereas Non-Hodgkin's lymphomas patients were the oldest. In the total sample, the median age was 58.2 years. A majority of patients were married or with a partner, and all disease stages were represented. All of the patients were included before the start of a chemotherapy treatment.

3.1.2. Confirmatory Factor Analysis (CFA)

Table 2 summarizes the CFA indices for the three MFI versions being compared (Fillion et al., 2003; Gentile et al., 2003; Smets et al., 1995). A good model fit was ascertained with a lower chi-square value at $p > .05$ (Barrett, 2007) but our results showed high chi-square values with a $p < .0001$. A good model was further confirmed by *RMSEA* values less than .08, whereas Table 2 indicated three indices higher than .115. In addition, our three tested models give us three *CFI* values lower than .90 whereas a *CFI* higher than .90 was expected (MacCallum et al., 1996). Those three versions showed an inadequate fit with regard to expected fit indices.

3.2. Study 2: Development and validation of a short-form MFI with cancer patients

3.2.1. Samples

The sample for study 1 was randomly divided into two subsamples (n = 211 participants for each sample). The first subsample was

Table 2
Fit indices for the confirmatory factor models of the MFI questionnaire.

Model	χ^2	*df*	*p-value*	CFI	RMSEA	95% CI (*p-value*)
Smets et al., 1996: 20 items/5 factors	1046.659	160	< .0001	0.848	0.115	0.108–0.121 (< .0001)
Gentile et al., 2003: 20 items/4 factors	1216.390	164	< .0001	0.820	0.123	0.117–0.130 (< .0001)
Fillion et al., 2003: 15 items/4 factors	481.719	70	< .0001	0.888	0.118	0.108–0.128 (< .0001)

Notes: CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; CI = Confidence Interval.

Table 3
Factor loadings estimates for ML with Promax rotation (N = 211) for the MFI-10 version.

MFI 10 items/3factors		F1 physical	F2 emotional	F3 cognitive
Item 2	Physically I feel only able to do a little	0.57	0.25	0.07
Item 5	I feel tired	0.73	−0.02	0.09
Item 14	Physically I feel I'm in a bad condition	0.76	0.23	−0.10
Item 16	I tire easily	0.95	−0.32	0.07
Item 9	I dread having to do things	0.12	0.62	0.20
Item 10	I think I do very little in a day	0.31	0.63	−0.14
Item 17	I get little done	0.02	0.59	0.27
Item 18	I don't feel like doing anything	−0.17	0.91	0.16
Item 13	It takes a lot of effort to concentrate on things	−0.01	0.20	0.79
Item 19	My thoughts easily wander	0.05	−0.02	0.61
SS loading/Eigen Values		2.55	2.22	1.18
Cumulative variance		0.26	0.48	0.60

considered as the calibration sample for the EFA, and the second as the replication sample for the CFA.

3.2.2. Exploratory factor analysis on MFI-10

We performed EFA for two, three and four-factor models. Table 3 shows the factor loadings (in boldface) of the 10 reversed items of the MFI. The EFA gave us a 3-factor structure which explained 60% of the variance. Every item loaded on a unique factor and provided a reasonable summary of the data providing an optimal meaningfully-interpretable solution. Indeed, factor 1 consisted of 4 items (2, 5, 14 and 16) that indicated lack of energy, and could be named "physical fatigue". The second factor comprised four items (9, 10, 17 and 18) that mainly reflected lack of motivation or weakness, and could be named "emotional fatigue." The third factor consisted of two items (13 and 19) that indicated difficulties concentrating or paying attention and could be named "cognitive fatigue." This 3-factor model had a KMO (Kaiser-Mayer-Olkin) = .93 and a Bartlett's test < .05, which is considered as excellent (Cerny and Kaiser, 1977).

3.2.3. Confirmatory Factor Analysis on MFI-10

CFA was performed to analyze the fit of this new 10-item 3-factor solution in the replication sample (n = 211). The fit indices for the 2-factor and 4-factor models were also reported for comparison (Table 4). Table 4 shows that our 3-factor model had the best fit indices. We obtained a $\chi^2 = 55.636$ which was the lowest between these three models. This three-factor solution gave us a RMSEA = .059 (95% CI [.032-.085]). In addition, we obtained a CFI equal to .978. This new version fit our data well. The 2-factor model also shows acceptable fit, but the 3-factors model was retained because of the "cognitive" dimension, which was particularly appropriate for our population.

Table 4
Fit indices summary of the 2-factors model, 3-factors model and 4 factor-model.

Model tested	χ^2 (*p*)	df	CFI	TLI	AIC	RMSEA
2-factors	59.885 (.004)	34	.976	.968	6585.015	.060
3-factors	55.636 (.006)	32	.978	.969	6584.766	.059
4-factors	61.553 (.001)	31	.971	.958	6592.682	.068

3.2.4. Construct validity

The Cronbach' alphas were respectively .80 for "physical fatigue", .88 for "emotional fatigue" and .70 for "cognitive fatigue". The composite reliability (CR) of two dimensions exceeds .80 with $CR_{\text{physical fatigue}} = .84$, $CR_{\text{emotional fatigue}} = .81$, satisfying the minimal acceptable value (Hair et al., 1998). Although the CR for the cognitive dimension did not reach the minimal value of .70 (CR = .54), we have chosen the 3-factor model for its appropriatedness to cancer patients (see also the *Discussion* section below).

The values of the convergent validity were acceptable for all the subscales: AVE "physical fatigue" = .58; AVE "emotional fatigue" = .52 and AVE "cognitive fatigue" = .58. Both ASV and MSV values for each dimensions were above the AVE values, and did not support the discriminant validity (Hair et al., 1998; Henseler et al., 2015). In a global fatigue questionnaire, assessing fatigue as multidimensional, the discriminant validity could be constrained by the conceptual similarity of the dimensions themselves. The same indices were calculated for the 2-factors model, which did not show discriminant validity either.

4. Discussion

This article presented two studies to discuss the structure of the MFI questionnaire and its psychometric properties. First, 15 different adaptations of the MFI were found in the literature. The main conclusions of this review were that (i) few studies reported a complete analysis with both exploratory and confirmatory analyses (in fact CFA was often not performed), and (ii) for the studies where CFA was computed, fit indices were not good (RMSEA > .10; CFI < .9) or the final structure of the MFI was changed. In addition, two studies which conducted a complete psychometric battery with data on cancer patients, found four or three dimensions of fatigue and deleted five items (Buss et al., 2014; Fillion et al., 2003). As the MFI includes 10 reversed items, this led us to discuss and focus on the items' wording. This idea confirms Woods et al.'s research in 2006 who found that "a scale containing reversed worded items would lead to an artificially created factor" resulting from response bias (Woods, 2006). This led us to develop and validate a new MFI version with 10 items only.

In our first study, we conducted a CFA with our samples on Smets' version, Gentile's version and Fillion's version (Fillion et al., 2003; Gentile et al., 2003; Smets et al., 1996), and those three models did not fit our data. None of the indices showed adequate fit and thus those models were rejected and not considered as the best explanation of the data. Then, we decided to conduct a second study to validate a MFI short-form by deleting reversed items. Our EFA on MFI-10 maintained all negative items (assessing fatigue) and showed a good three-dimensional structure.

The items comprising the dimensions were very understandable; factor 1 comprised four items (" Physically, I feel only able to do a little", "I feel tired", "Physically, I feel I am in a bad condition" and "I tire easily") that mainly reflected lack of energy and could be named "Physical fatigue." The item "I feel tired" is meaningful when you work

with cancer patients. In addition, two items started with "physically" which address the physical dimension. The second factor "Emotional fatigue" consisted of 4 items that indicated a lack of motivation or weakness ("I dread having to do things", "I think I do very little in a day", "I get little done," "I don't feel like doing anything"). This finding is specific to our population; cancer patients experience fatigue in a different way because of its persistence that causes distress or interferes with their daily activities or functioning (NCCN National Comprehensive Cancer Network, 2017). This particularity leads to a strong weakness and a lack of motivation in daily life, understandable because of the diagnosis, the care routine and the weariness generated. These results corroborate those found in previous work, in which patients interviewed about their fatigue distinguished physical fatigue from emotional fatigue (Baussard et al., 2017). In the interviews, a majority of patients used the French term "lassitude," which can be translated as weariness and may evoke depressive symptoms (Baussard et al., 2017). Factor 3 comprised two items ("It takes a lot of efforts to concentrate on things" and "My thoughts easily wander") that indicated difficulties concentrating or paying attention and could be named "cognitive fatigue." We have chosen to keep this dimension despite the fact that some indices were not good enough ($CR_{cognitive\ fatigue} = .54$; AVE < MSV-ASV values). This choice is argued by the cognitive impact of cancer treaments on patients, as chemotherapy is known to reduce attention, concentration and memorization (Jim et al., 2012). The patient types were metastatic colorectal cancer (168 patients) and Non-Hodgkin's lymphomas (43 patients). Metastatic patients in our sample were diagnosed three years before the study on average; the more chemotherapy they received, the more side effects they experienced, such as fatigue, declining eye-sight or inattention (Wagland et al., 2015). In addition, Non-Hodgkin's lymphomas patients are characterized by an advanced age and an important cognitive impairment (Krolak et al., 2017; Zimmer et al., 2015). We believe that it is important to keep this third factor, because of its meaning in cancer patients.

4.1. Study limitations

We created our adaptation of the MFI with the assumption that measuring fatigue in a population of cancer patients is different from measuring fatigue in healthy people. Our adaptation only targets the specific population of cancer patients and may not be generalized to other populations. For example, our 3-factors solution depends on a "cognitive fatigue" dimension which explained 12% of the variance with only two items. This cognitive fatigue is argued by the fact that cancer treatments, especially chemotherapy, affect cognitive functions (Jim et al., 2012; Wagland et al., 2015). In addition, deleting 10 items in a questionnaire containing 20 items is ambitious. Future analyses on a clinical sample of cancer patients are warranted to further evaluate the validity of the MFI-10. For us, cutting the questionnaire in half is motivated by our specific population and the specific area of nursing care.

4.2. Implications for nursing

Strasser et al. (Strasser et al., 2009) concluded that "future research must address the development of a generalizable instrument that is currently validated and the testing of the hypothesis that fatigue-domain screening can reliably guide fatigue domain-specific treatments in clinical practice, facilitate interdisciplinary management, and improve fatigue-related outcomes" (Strasser et al., 2009). The MFI-10 has the advantage to save time for clinicians, nurses and researchers dealing with cancer patients, while maintaining good psychometric qualities. We created a multidimensional tool which defines fatigue across three dimensions with an acceptable fit, and a meaningful interpretation of score dimensions (the higher the value on the Likert-scale, the more the fatigue symptom is present).

Declarations of interest

None.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejon.2018.07.005.

References

Ahlberg, K., Ekman, T., Gaston-Johansson, F., Mock, V., 2003. Assessment and management of cancer-related fatigue in adults. Lancet 362 (9384), 640–650.

Baptista, R.L.R., Biasoli, I., Scheliga, A., Soares, A., Brabo, E., Morais, J.C., et al., 2012. Psychometric properties of the multidimensional fatigue inventory in Brazilian Hodgkin's lymphoma survivors. J. Pain Symptom Manag. 44 (6), 908–915. https://doi.org/10.1016/j.jpainsymman.2011.12.275.

Barrett, P., 2007. Structural equation modelling: adjudging model fit. Pers. Indiv. Differ. 42 (5), 815–824. https://doi.org/10.1016/j.paid.2006.09.018.

Baussard, L., Stoebner-Delbarre, A., Bonnabel, Laurence, Huteau, M.-E., Gastou, A., Cousson-Gélie, F., 2017. Development and validation of the daily fatigue cancer scale (DFCS): single-item questions for clinical practice. European Journal of Cancer Nursing 26, 42–48.

Baussard, L., Ychou, M., Senesse, P., Khemissa, F., Mineur, L., Proust-Lima, C., Cousson-Gélie, F., 2016. Abstracts. Psycho Oncol. 25 (SP. SP) 13–13. https://doi.org/10.1002/pon.4272.

Berger, A.M., Mooney, K., Alvarez-Perez, A., Breitbart, W.S., Carpenter, K.M., Cella, D., et al., 2015. Cancer-related fatigue, version 2.2015. J. Natl. Compr. Canc. Netw.: J. Natl. Compr. Canc. Netw. 13 (8), 1012–1039.

Buss, T., Kruk, A., Wiśniewski, P., Modlinska, A., Janiszewska, J., Lichodziejewska-Niemierko, M., 2014. Psychometric properties of the polish version of the multidimensional fatigue Inventory-20 in cancer patients. J. Pain Symptom Manag. 48 (4), 730–737. https://doi.org/10.1016/j.jpainsymman.2013.11.015.

Carayol, M., Romieu, G., Bleuse, J.-P., Senesse, P., Gourgou-Bourgade, S., Sari, C., et al., 2013. Adapted physical activity and diet (APAD) during adjuvant breast cancer therapy: design and implementation of a prospective randomized controlled trial. Contemp. Clin. Trials 36 (2), 531–543. https://doi.org/10.1016/j.cct.2013.09.016.

Cerny, B.A., Kaiser, H.F., 1977. A study of a measure of sampling adequacy for factor-analytic correlation matrices. Multivariate Behav. Res. 12 (1), 43–47.

Chandel, P., Sultan, A., Khan, K., Choudhary, V., Parganiha, A., 2015. Validation of the Hindi version of the multidimensional fatigue Inventory-20 (MFI-20) in indian cancer patients. Support. Care Canc. 23 (10), 2957–2964. https://doi.org/10.1007/s00520-015-2661-5.

Chilcot, J., Guirguis, A., Friedli, K., Almond, M., Davenport, A., Day, C., et al., 2017. Measuring fatigue using the multidimensional fatigue Inventory-20: a questionable factor structure in haemodialysis patients. Nephron 136 (2), 121–126. https://doi.org/10.1159/000458770.

Cousson-Gélie, F., Allart, P., de Chalvron, S., Soubeyran, P., 2013. Determinants and changes in psychological adaptation and quality of life during chemotherapy for diffuse large B cell non-hodgkin's lymphoma in the vulnerable and frail elderly ("psy-frail" study): p1-79. Pscyho-Oncology 22, 171–172.

Elbers, R.G., van Wegen, E.E.H., Verhoef, J., Kwakkel, G., 2012. Reliability and structural validity of the Multidimensional Fatigue Inventory (MFI) in patients with idiopathic Parkinson's disease. Park. Relat. Disord. 18 (5), 532–536. https://doi.org/10.1016/j.parkreldis.2012.01.024.

Farrell, A.M., Rudd, J.M., 2009. In: Tojib, D. (Ed.), Factor Analysis and Discriminant Validity:a Brief Review of Some Practical Issues. ANZMAC Retrieved from. http://publications.aston.ac.uk/7644/.

Fillion, L., Gélinas, C., Simard, S., Savard, J., Gagnon, P., 2003. Validation evidence for the French canadian adaptation of the multidimensional fatigue inventory as a measure of cancer-related fatigue. Canc. Nurs. 26 (2), 143–154.

Gentile, S., Delarozière, J.C., Favre, F., Sambuc, R., San Marco, J.L., 2003. Validation of the French "multidimensional fatigue inventory" (MFI 20). Eur. J. Canc. Care 12 (1), 58–64.

Glaus, A., Crow, R., Hammond, S., 1996. A qualitative study to explore the concept of fatigue/tiredness in cancer patients and in healthy individuals. Eur. J. Canc. Care 5, 8–23. https://doi.org/10.1111/j.1365-2354.1996.tb00247.x.

Globocan 2012-Home. (n.d.). Retrieved May 25, 2018, from http://globocan.iarc.fr/Default.aspx.

Hafezi, S., Zare, H., Mehri, S.N., Mahmoodi, H., 2010. The Multidimensional Fatigue Inventory validation and fatigue assessment in Iranian distance education students. In: 2010 4th International Conference on Distance Learning and Education, pp. 195–198. https://doi.org/10.1109/ICDLE.2010.5606006.

Hair, J., Anderson, R.E., Tatham, R.L., Black, W.C., 1998. In: Multivariate Data Analysis, fifth ed. .

Henseler, J., Ringle, C.M., Sarstedt, M., 2015. A new criterion for assessing discriminant validity in variance-based structural equation modeling. J. Acad. Market. Sci. 43 (12), 115–135.

Jim, H.S.L., Phillips, K.M., Chait, S., Anne Faul, L., Popa, M.A., Lee, Y.-H., et al., 2012. Meta-analysis of cognitive functioning in breast cancer survivors previously treated with standard-dose chemotherapy. J. Clin. Oncol. 30 (29), 3578–3587. https://doi.org/10.1200/JCO.2011.39.5640.

Krolak, D., Collins, B., Weiss, L., Harris, C., Jagt, R. V. der, 2017. Cognitive function and its relationship to other psychosocial factors in lymphoma survivors. Support. Care Canc. 25 (3), 905–913. https://doi.org/10.1007/s00520-016-3480-z.

Lawrence, D.P., Kupelnick, B., Miller, K., Devine, D., Lau, J., 2004. Evidence report on the occurrence, assessment, and treatment of fatigue in cancer patients. JNCI Monographs (32), 40–50. 2004. https://doi.org/10.1093/jncimonographs/lgh027.

Lee, K.A., Hicks, G., Nino-Murcia, G., 1991. Validity and reliability of a scale to assess fatigue. Psychiatr. Res. 36 (3), 291–298. https://doi.org/10.1016/0165-1781(91)90027-M.

Lin, J.M.S., Brimmer, D.J., Maloney, E.M., Nyarko, E., BeLue, R., Reeves, W.C., 2009. Further validation of the Multidimensional Fatigue Inventory in a US adult population sample. Popul. Health Metrics 7 (18). https://doi.org/10.1186/1478-7954-7-18.

Lundh Hagelin, C., Wengström, Y., Runesdotter, S., Fürst, C.J., 2007. The psychometric properties of the Swedish Multidimensional Fatigue Inventory MFI-20 in four different populations. Acta Oncol. 46, 97–104.

MacCallum, R.C., Browne, M.W., Sugawara, H.M., 1996. Power analysis and determination of sample size for covariance structure modeling. Psychol. Meth. 1 (2), 130.

Maroco, J., 2010. Análise de Equações Estruturais: Fundamentos teóricos, software & Aplicações. (. ReportNumber, Lda). .

Meek, P.M., Nail, L.M., Barsevick, A.M., Schwartz, A.L., Stephen, S., Whitmer, K., et al., 2000. Psychometric testing of fatigue instruments for use with cancer patients. Nurs. Res. 49 (4), 181–190.

Minton, O., Stone, P., 2009. A systematic review of the scales used for the measurement of cancer-related fatigue (CRF). Annals of Oncology Advance 20 (1), 17–25.

Munguía-Izquierdo, D., Segura-Jiménez, V., Camiletti-Moirón, D., Pulido-Martos, M., Alvarez-Gallardo, I.C., Romero, A., et al., 2012. Multidimensional fatigue inventory: Spanish adaptation and psychometric properties for fibromyalgia patients. The Al-Andalus study. Clin. Exp. Rheumatol. 30 (Suppl 74), 94–102.

NCCN National Comprehensive Cancer Network, 2017. Cancer-related Fatigue (NCCN Clinical Pratice Guidelines in Oncology No. 2.2017). NCCN.Org. Retrieved from https://www.nccn.org/professionals/physician_gls/pdf/fatigue.pdf.

Porro, B., Michel, A., Trentini, F., Monrigal, E., Pierre, B., Zinzindohoue, C., Cousson-Gélie, F., 2016. Identification of psychosocial factors affecting job retention of women with breast cancer. A pilot study. Eur. Health Psychol. 18 (S), 1077.

Prue, G., Rankin, J., Allen, J., Gracey, J., Cramp, F., 2006. Cancer-related fatigue: a critical appraisal. Eur. J. Cancer 42 (7), 846–863. https://doi.org/10.1016/j.ejca.2005.11.026.

R Core Team, 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Raiche, G., 2010. nFactors: a R Package to Parallel Analysis and Non Graphical Solutions to the Cattell Scree Test.

Revelle, W., 2014. CRAN - Package Psych. Retrieved November 9, 2017, from. http://www2.uaem.mx/r-mirror/web/packages/psych/.

Rhemtulla, M., Brosseau-Liard, P.É., Savalei, V., 2012. When can categorical variables be treated as continuous? A comparison of robust continuous and categorical SEM estimation methods under suboptimal conditions. Psychol. Meth. 17 (3), 354–373. https://doi.org/10.1037/a0029315.

Rosseel, Y., 2012. Lavaan: an R Package for Structural Equation Modeling and More Version 0.5-12 (BETA).

Schneider, R.A., 1998. Reliability and validity of the multidimensional fatigue inventory (MFI-20) and the rhoten fatigue scale among rural cancer outpatients. Canc. Nurs. 21 (5), 370–373.

Shacham, S., 1983. A shortened version of the profile of Mood states. J. Pers. Assess. 47 (3), 305–306. https://doi.org/10.1207/s15327752jpa4703_14.

Smets, E.M.A., Garssen, B., Bonke, B., De Haes, J.C.J.M., 1995. The multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. J. Psychosom. Res. 39 (3), 315–325. https://doi.org/10.1016/0022-3999(94)00125-O.

Smets, E.M.A., Garssen, B., Cull, A., de Haes, J., 1996. Application of the multidimensional fatigue inventory (MFI-20) in cancer patients receiving radiotherapy. Br. J. Canc. 73 (2), bjc199642. https://doi.org/10.1038/bjc.1996.42.

Strasser, F., Müller-Käser, I., Dietrich, D., 2009. Evaluating cognitive, emotional, and physical fatigue domains in daily practice by single-item questions in patients with advanced cancer: a cross-sectional pragmatic study. J. Pain Symptom Manag. 38 (4), 505–514. https://doi.org/10.1016/j.jpainsymman.2008.12.009.

Tack, B.B., 1991. Dimensions and Correlates of Fatigue in Older Adults with Rheumatoid Arthritis.

Tian, J., Hong, J.-S., 2012. Validation of the Chinese version of multidimensional fatigue Inventory-20 in Chinese patients with cancer. Support. Care Canc. 20 (10), 2379–2383. https://doi.org/10.1007/s00520-011-1357-8.

Torre, L.A., Bray, F., Siegel, R.L., Ferlay, J., Lortet-Tieulent, J., Jemal, A., 2015. Global cancer statistics, 2012. CA A Cancer J. Clin. 65 (2), 87–108. https://doi.org/10.3322/caac.21262.

Van Sonderen, van, E., Sanderman, R., Coyne, J.C., 2013. Ineffectiveness of reverse wording of questionnaire items: let's learn from cows in the rain. PLoS One 8 (7), e68967. https://doi.org/10.1371/journal.pone.0068967.

Wagland, R., Richardson, A., Armes, J., Hankins, M., Lennan, E., Griffiths, P., 2015. Treatment-related problems experienced by cancer patients undergoing chemotherapy: a scoping review. Eur. J. Canc. Care 24 (5), 605–617. https://doi.org/10.1111/ecc.12246.

Woods, C., 2006. Careless responding to reverse-worded items: implications for confirmatory factor analysis. J. Psychopathol. Behav. Assess. 28, 186–191. https://doi.org/10.1007/s10862-005-9004-7.

Zimmer, P., Mierau, A., Bloch, W., Strüder, H.K., Hülsdünker, T., Schenk, A., et al., 2015. Post-chemotherapy cognitive impairment in patients with B-cell non-Hodgkin lymphoma: a first comprehensive approach to determine cognitive impairments after treatment with rituximab, cyclophosphamide, doxorubicin, vincristine and prednisone or rituximab and bendamustine. Leuk. Lymphoma 56 (2), 347–352. https://doi.org/10.3109/10428194.2014.915546.