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Lee Fatigue and Energy Scales: Exploring aspects of validity in a sample of women with HIV using an application of a Rasch model

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Abstract

This study examines the psychometric properties of the Lee Fatigue and Energy Scales (visual analog version) using a Rasch model application. The relationship between fatigue and energy is also described for a convenience sample of 102 women with HIV/AIDS who completed the Lee Fatigue and Energy Scales in the morning and evening. Both scales were assessed for internal scale validity, unidimensionality, and uniform differential item functioning in relation to morning and evening ratings. Analyses confirmed that both the Fatigue and Energy Scales demonstrated evidence of internal scale validity and unidimensionality. Mean fatigue measures were also higher in the evening than in the morning and mean energy measures were higher in the morning than in the evening (both $p<0.001$), indicating that time of day is an important consideration. Fatigue and energy measures were moderately correlated with each other in the morning but not in the evening. The concepts of energy and fatigue were inversely related, but not polar opposites in this sample. Fatigue and energy may therefore be distinct constructs that should not be used interchangeably, either in measurement or when interpreting outcomes for research or clinical purposes.

Keywords

Psychometrics; Measurement; Quality of Life; Symptoms; Rasch analysis

1. Introduction

The psychometric properties of Lee's Fatigue and Energy Scales were initially evaluated in samples of healthy and sleep disturbed adults (Lee et al., 1991) and adults with cancer (Meek et al, 2000) using classical test theory approaches. Since then, the scales have been

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widely used in a variety of populations with chronic illness (Schaefer, 1995; Lee et al., 1999; Borge et al., 2010; Lerdal et al., 2011; Miaskowski et al., 2011). In classical test theory, it is assumed that data used are based upon interval or ratio scales (Bond and Fox, 2007), and the evaluation of the psychometric properties of an instrument is often based upon this assumption. However, in assessing fatigue, ordinal scales are commonly used and the risk of misinterpretation of psychometric statistical outcomes may therefore increase (Merbitz et al., 1989; Wright and Linacre, 1989). To overcome this issue, Rasch measurement models can be applied as a complementary approach (Tesio, 2003). The Rasch measurement model is increasingly used in the development and validation of assessments measuring different aspects of human performance and experience, such as fatigue (Tesio, 2003). Rasch models also have the advantage of providing in-depth evaluation of individual item and person patterns of responses, which can provide additional information about an instrument's substantive, content, structural, generalizability, and external validity (Wolfe & Smith, 2007a). Thus, the psychometric properties of many established instruments are now reassessed using Rasch models (e.g., Pallant and Tennant, 2007; Siegert et al., 2010) in order to provide additional evidence of validity, but also to suggest further areas for improvement.

Fatigue is a complex multidimensional symptom, which has been defined as a sense of exhaustion, lack of energy, or tiredness distinct from sleepiness, sadness, or weakness (Krupp et al., 1988; Lee et al., 1994; Lerdal, 1998). Fatigue is a common symptom among adults with chronic illness and negatively impacts quality of life (Voss, 2005; Hofman et al., 2007; Bennett et al., 2010). Among adults living with HIV/AIDS, Marcellin and colleagues (2007) found that self reported fatigue was a main indicator of health-related quality of life. However, the subjective nature of fatigue can make it difficult for health care providers to understand how seriously it impacts patients' lives (Jenkin et al., 2006). Furthermore, it remains unclear whether the experience of fatigue in the context of chronic illness differs from that of healthy adults and to what extent fatigue experiences differ across diseases.

Perceived energy has received less attention in the research literature, but has been defined as: "the individuals' potential to perform physical and mental activity" (Lerdal, 1998, p. 9.). Energy is a central factor when people evaluate their health and represent both a mental and physical capacity to do work that may be managed e.g. by economizing strategies (Lerdal, 2002). An intervention study (Jason et al., 2009) of patients with myalgic encephalomyelitis/ chronic fatigue syndrome showed that those who reported higher weekly level of energy in relation to weekly expended energy reported a reduction in their fatigue during the 12-month study. Those who reported lower weekly perceived energy level in relation to weekly expended energy reported no change in fatigue during the 12-month follow-up, suggesting that the relationship between fatigue and energy may not be linear. The concept of energy is used in most definitions of fatigue, and a factor analysis of the Lee Fatigue and Energy Scales identified them as separate, but related concepts (Lee, 1993), although limited empirical research exists on the relationship between the fatigue and energy constructs.

Assessment of fatigue and energy should address how these symptoms fluctuate across the day (Dimsdale et al., 2003); typically fatigue levels are higher in the evening than in the morning, and energy levels are higher in the morning than in the evening (Lee, Hicks, and Nino-Murcia, 1991). Despite this knowledge, most prior research on fatigue has assessed average fatigue levels across broad time frames, such as during the past week or month (e.g., Henderson et al., 2005; Pence et al., 2008) and has not examined daily fluctuations between morning and evening. A recent study (Lerdal et al., 2011) indicates that the fluctuating patterns of morning and evening fatigue have clinical relevance and are associated with different symptom experiences. Whether similar patterns exist for energy has yet to be determined.

To facilitate future research in assessing fatigue among adults with chronic illness, this study examines some key psychometric properties (substantive, content, structural, and generalizability validity) of the Lee Fatigue and Energy Scales using a Rasch model in a sample of chronically ill women. This study also describes the relationship between fatigue and energy measures in this sample both in the morning and in the evening.

2. Methods

2.1. Sample

The original study used a cross sectional design to describe fatigue and energy in a convenience sample of 107 ethnically diverse women living with HIV/AIDS between 1994 and 1997. Potential participants were accessed through their heath care provider at agencies primarily serving Medi-Cal/Medicaid patients in the San Francisco Bay Area. To be eligible, women had to be at least 18 years of age, able to understand and sign an English consent form, and living with HIV/AIDS. Given the potential for some conditions to affect the reliability and validity of the fatigue and energy measures, women were excluded from the study if they were diagnosed with AIDS dementia or moderate neuropathy, hospitalized in the past week, pregnant or lactating in the last 6 months, or currently using illicit substances. Women who met the eligibility criteria were provided with information about the study, and all women approached agreed to participate.

2.2. Procedures

Each woman provided informed consent prior to study participation and was paid $25.00 upon completion. Each participant's most recent CD4 T-cell count was obtained from her medical record. Demographic information and time since HIV diagnosis were obtained by self-report (see Table 1)

2.3. Instrument and data collection

Participants completed the Lee Fatigue and Energy Scales within 15 minutes of bedtime each evening and within 15 minutes of waking each morning over a 48-hour monitoring period. The Lee Fatigue and Energy Scales have established internal consistency reliability in a variety of populations, and concurrent validity with other fatigue measures has been previously established in healthy and sleep-disordered samples (Lee et al., 1991). The Scales consist of 18 items and take less than 2 minutes to complete. Based on a prior factor analysis in a sample of healthy individuals and patients with sleep disorders (Lee, 1993), the 18 items are divided into a 13-item Fatigue scale and a 5-item Energy scale (sample items and format shown in Table 2). Each item has a 100-mm visual analogue line with descriptors at both ends, and respondents mark the line to indicate how they currently feel. The score for each item is the distance in mm between the left end of the line and the respondent's mark. The Fatigue Scale score is calculated as the mean of the 13 fatigue items, and the Energy Scale score is the mean of the 5 energy items. Higher scores on the Fatigue Scale represent greater fatigue severity, and higher scores on the Energy Scale indicate higher levels of energy.

2.4. Statistical analysis

SPSS for Windows Version 17.0 software (SPSS Inc., IL, USA) was used to summarize sample demographic and clinical characteristics and their associations with fatigue and energy ratings, compare morning and evening scores using paired *t*-tests, and determine correlations between Energy and Fatigue scales using Pearson's product moment correlations. The level of significance was set at $p<0.05$, and all tests were two-tailed.

Because the validity of the Lee Fatigue and Energy Scales has only been evaluated to a limited extent, a polytomous rating scale Rasch model was chosen to analyze the raw scores in order to generate valid measures of fatigue and energy both in the morning and in the evening. The Rasch model was chosen to evaluate the Scales for three reasons. First, items in the Scales represent different aspects of fatigue and energy that are assumed to vary in severity. The Rasch model takes each item scored by the participant and adjusts the final person-measure based on relative differences in item severity. Secondly, Rasch models are suitable for handling data with items that are missing at random. Even though only 15 (1%) of the scores in the Fatigue Scale and 37 (2%) of the scores in the Energy Scale were missing, we did not have to exclude any participant due to missing values in order to use the Rasch modelling procedure (Wright and Stone, 1979; Bond and Fox, 2001; Linacre, 2010). Finally, a Rasch rating scale model was selected because all items contained in the Lee Fatigue and Energy Scales are scored on a similar scale (Wolfe and Smith, Jr., 2007a). The Rasch analytic approach is summarized in Table 3.

The WINSTEPS analysis software program, version 3.69.1.16 (Linacre, 2010) was used to conduct the Rasch analysis of the Lee Fatigue and Energy Scales. For the Rasch analysis, scores on the 100-mm visual analog lines were recoded into 10 rating scale categories/scores ranging from 1 (0–10 mm) to 10 (91–100 mm). A polytomous Rasch model analysis then converted the raw item scores from the questionnaire into equal-interval measures using a logarithmic transformation of the odds probabilities of responses. The converted measures are then used to examine whether items/statements from a scale measure a unidimensional construct, viewed as crucial in both classical and modern test statistics (Spector, 1992; Bond and Fox, 2001). Rasch models are probabilistic and based on theoretical assertions against which the actual pattern of responses is validated.

The substantive validity of the Lee Fatigue and Energy rating scales were initially evaluated with the following criteria: a) each rating scale category should contain a minimum of ten observations, b) the average measures for each item rating scale category on each item should advance monotonically, and b) a criterion less than 2.0 was expected in outfit mean square *(MnSq)* values for rating scale category calibrations (Linacre, 2002; Linacre, 2004). The fit of the items to each of the Rasch models was then analyzed followed by principal component analyses to address unidimensionality.

Evidence of content validity was investigated using item goodness-of-fit statistics using the WINSTEPS program to generate mean square (*MnSq*) residuals and standardized *z*-values for each of the thirteen (Fatigue) and five (Energy) items. These goodness-of-fit statistics indicate the degree of match between actual responses on the Fatigue and Energy Scales and expected responses from the Rasch model. Goodness-of-fit was evaluated using infit statistics. Infit statistics are information-weighted fit statistics that give relatively more weight to the unexpected responses among persons who are well targeted to the item calibrations. As infit statistics are more informative when exploring the fit of the items to the Rasch model (Wright and Masters, 1982; Bond and Fox, 2007), we chose infit statistics to evaluate goodness-of-fit across individual items. The *MnSq* fit statistic has an expected value of 1.0 and is preferable for item goodness-of-fit with polytomous data (as in the Fatigue and Energy Scales) as it is less sensitive to sample (Smith et al., 2008). We chose to use a sample-size adjusted criterion (Smith et al., 2008) for item goodness-of-fit set for infit *MnSq* values between 0.7 and 1.3 logits.

To minimize risk of additional explanatory factors, a *principal component analysis* (PCA) of residuals was also performed to evaluate structural validity of the Fatigue and Energy Scales (Linacre, 2010). The criterion was set for at least 50% of the total variance that should be explained by the first latent variable (Smith and Miao, 1994). In order to evaluate validity in relation to generalizability, a differential item functioning (DIF) analysis was also performed to explore the stability of response patterns in relation to the items of the Fatigue and Energy

Scales in the morning and evening. The magnitude of DIF was evaluated using the Mantel-Haenszel statistic for polytomous scales using log-odds estimators (Mantel and Haenzel, 1959; Mantel, 1963) in the WINSTEPS program ($p < .05$).

2.5. Ethics

The study was approved by the Committee on Human Research at the University of California, San Francisco. All participants provided written informed consent.

3. Results

3.1. Study sample and descriptive statistics

A sample of 107 women living with HIV/AIDS was enrolled in the study, and 102 women with fatigue data were included in this analysis. Although two evening and two morning ratings were completed during the 48-hour monitoring period and the findings were similar for both days, only data from the first evening and first morning are reported in this analysis. Sample demographics, clinical characteristics, and mean Fatigue and Energy Scale scores are reported in Table 1.

3.2. Rasch analysis of the Fatigue and Energy Scales

When evaluating the Fatigue Scale, all ten rating scale categories were used more than ten times, the average measures for each item category/score (1 to 10) advanced monotonically, and all thirteen items met the criterion set for item goodness-of-fit (see Table 3). The principal components analysis revealed that the first component explained 52.1% of the total variance in Fatigue Scale scores, which exceeded the criterion of at least 50%.

When evaluating the Energy Scale, all ten rating scale categories were used more than ten times, but the average measures for each item category/score did not advance monotonically. The rating scale categories 8, 9, and 10 were in some items ordered illogically (10, 8, 9). We therefore decided to collapse those categories and re-evaluate the scale. After collapsing the scale categories, the Energy Scale met both criteria set. We therefore proceeded with the analysis using a collapsed category for 8, 9, 10. All five items in the Energy Scale met the criterion set for item goodness-of-fit. The principal component analysis revealed that the first component explained 63.5% of the variance in Energy Scale scores, which exceeded the criterion of at least 50%.

3.3. Differential item functioning (DIF)

For a more in depth exploration of potential variations in the item response patterns in relation to relevant sample variables, we performed a series of differential item functioning (DIF*)* analyses (see Table 3). On the Fatigue Scale, one of the 13 items demonstrated DIF in relation to education. Relative to other items, Item 13 *(Keeping my eyes open is no effort at all)* was easier to agree with among those who had not completed high school compared to those who had completed high school. In addition, two of the 13 fatigue items demonstrated significant DIF in relation to time of day. Relative to other items, Item 14 (*Moving my body is no effort at all/Moving my body is a tremendous chore)* was easier to agree with in the evening compared to in the morning ($p < 0.05$). In an opposite pattern, Item 18 (*I have absolutely no desire to lie down/I have a tremendous desire to lie down)* was harder to agree with in the evening compared to the morning relative to other items ($p < 0.001$). Although the individual Fatigue Scale scores were overall higher in the evening than in the morning, this fatigue increase in the evening was demonstrated to a lesser extent on Item 18 and to a greater extent on Item 14. Of the five items of the Energy Scale, one demonstrated DIF in relation to education. Relative to other items, Item 8 (*Vigorous*) was easier to agree with among those who had not completed high school.

3.4 Relationships between morning and evening ratings and between the Fatigue and Energy Scales

Once the Rasch-generated measures were confirmed to demonstrate evidence of substantive, content, structural and generalization validity, relationships between the Fatigue and Energy Scales and the differences between morning and evening ratings were evaluated. Fatigue Scale measures were found to be significantly higher in the evening than in the morning, $t(98) = -5.35$, $p < 0.001$, and Energy Scale measures were found to be higher in the morning than in the evening, $t(96) = 2.46$, $p < .05$. In addition to being significantly different, the morning and evening measures were only moderately correlated for both the Fatigue ($r = 0.38$; $p < .01$) and Energy Scales ($r = 0.22$; $p < .05$). Fatigue and Energy Scale scores were inversely correlated in the morning ($r = -0.31$; $p < .01$) and not correlated in the evening ($r = 0.05$, NS), suggesting that the measures may be influenced differently by rest and sleep behavior during the night in this sample of chronically ill women.

4. Discussion

The results of this study provide evidence for the internal scale validity and unidimensionality of the Fatigue and Energy Scales, as well as the uniform differential item functioning in relation to morning and evening ratings. Prior psychometric evaluations of these scales addressed aspects of content and external validity, as well as internal consistency reliability (Lee et al., 1991, Lee, et al., 1999, Meek et al., 2000), but the findings of this Rasch-based analysis expand the psychometric evaluation to include aspects of substantive, content, structural, and generalizability validity (Messick, 1995, Wolfe & Smith, 2007b).

For all items in the Fatigue Scale and for three of the five Energy Scale items, the average measures for each of the 10 response categories advanced monotonically, indicating that each rating category distinguished different levels of fatigue or energy. However, the highest scores (8, 9, and 10) on three of the Energy Scale items did not seem to distinguish different levels of energy. This issue will need to be evaluated in future studies using the Energy Scale, as these results indicate that the precision of the higher scores may be questionable for women with HIV/AIDS.

The finding of unidimensionality supports the inclusion of sleepiness-related items in the Fatigue Scale. Although the concepts of sleepiness and fatigue are often differentiated conceptually (Chambers and Docktor, 1993), the constructs were indistinguishable in a previous factor analysis of the items for healthy adults and adults with sleep disorders (Lee, 1993) and in this current Rasch analysis with HIV chronic illness. It is possible that the constructs of fatigue and sleepiness are only distinguishable using some instruments or in specific populations. Further research is needed to better understand the distinctions and overlaps between these constructs.

In this sample, women living with HIV/AIDS evaluated their level of energy differently from their level of fatigue. Fatigue and Energy Scale scores were only weakly correlated, a finding that supports a prior principal component analysis among healthy adults and patients with sleep disorders (Lee et al., 1991; Lee, 1993). However, the inconsistent and relatively weak associations between fatigue and energy in the current study raises questions about definitions of fatigue that incorporate “lack of energy” (Lerdal, 2002; Krupp, 2006). These findings also support the recommendation not to combine the Fatigue and Energy Scales into a single overall score. Evaluating fatigue and energy separately will facilitate further research in determining how they relate to each other. One possibility that needs further exploration is that the relationship between energy and fatigue may not be linear, such that these constructs are only correlated when fatigue is high or when energy is low.

There is a growing body of research on the relationship of fatigue to other symptoms, such as depression, anxiety, stress, and sleep disturbance, as well as to daily functioning and quality of life (Lerdal et al., 2009; Barroso et al., 2010). Although there is little research specifically addressing perceived energy, our recent study of energy and fatigue in a sample of men and women with HIV/AIDS (Aouizerat et al., in press) indicated that perceived lack of energy was a stronger predictor of interference in daytime function than was fatigue. One explanation for this finding is that the descriptors of energy often imply a behavioral component (e.g., active and vigorous), in contrast to typical descriptors of fatigue that focus on subjective experience (e.g., feeling tired or worn-out). As such, energy might be expected to have stronger associations than fatigue with outcomes that require some level of activity, such as daytime functioning, treatment regimen adherence, and quality of life measures.

Given the results of this study and other recent research, the concepts of energy and fatigue need clear and distinct definitions. We propose a theoretical definition of fatigue that does not include the concept of energy: “a feeling of tiredness or exhaustion that varies from morning to evening and is distinct from sadness or weakness.” In contrast, a previously proposed definition of energy is: “the individuals’ potential to perform physical and mental activity” (Lerdal, 1998, p.9). Based on these definitions, energy may be something individuals utilize to manage fatigue. Individuals can feel fatigued, but as long as they can muster some energy, they can still function. However, if energy cannot be generated, function suffers. Clear and distinct definitions of these constructs will facilitate research in determining the relative importance of fatigue and energy in predicting health-related outcomes and in developing and testing potential targeted interventions.

In this sample of women living with HIV/AIDS, time of day was a significant factor influencing the fatigue and energy ratings. Fatigue Scale scores were higher in the evening than in the morning, and Energy Scale scores were higher in the morning than in the evening. Morning and evening measures were moderately correlated for both the Fatigue Scale ($r = 0.38$) and the Energy Scale ($r = 0.22$). Furthermore, the two items on the Fatigue Scale that demonstrated DIF in relation to morning and evening ratings may reflect clinically important differences in the fluctuation of energy and fatigue rather than psychometric validity weaknesses of the Lee Fatigue and Energy Scales. Nonetheless, it may still be important to explore the effects of diagnostic/clinical DIF upon such measures / estimations, as otherwise interpretations of findings may be biased. Other Rasch-based studies (Kottorp et al., 2003; Petersson et al., 2008) have used DIF analyses to reveal both diagnostic profiles as well as intervention effects, and larger longitudinal studies will therefore be helpful in revealing such diurnal patterns in fatigue and energy, and the impact of such patterns on measures/estimations. Our previous research (Lerdal et al., 2011) suggests that different diurnal patterns of fatigue are associated with different symptom experiences, but further research is needed to identify possible clinical implications of different patterns of energy.

The findings from this study should be considered in context of certain limitations. Because this study is based on a sample of women with HIV/AIDS, the findings may not generalize to men, other chronic illnesses, or healthy populations. Future research is warranted in these other populations, and differential item functioning (DIF) should be examined by gender. There are numerous potential confounds (e.g., nighttime and daytime sleep, medications, and other comorbid conditions such as depression or anxiety disorders) that might influence fatigue and energy ratings. Such confounds were not evaluated as part of this study, and need to be addressed in future studies. In this study, patients’ scores on a 100-mm visual analog scale were converted to a numeric 10-point scale for Rasch analysis. While the results might generalize to other studies using the 100-mm visual analog scale, the findings may not generalize to versions of the Fatigue and Energy Scales that utilize a modified 11-

point numeric rating scale of 0 to 10 (Meek et al., 2000; Lerdal et al., 2011). The numeric rating scale version is often called the Lee Fatigue Scale (LFS), and this study needs replication with the LFS.

In summary, findings from this Rasch analysis indicate that the Lee Fatigue and Energy Scales demonstrate evidence of substantive, content, structural and generalizability validity when assessing fatigue and energy in women with HIV/AIDS. Results also suggest that fatigue is not merely the absence of energy, and that fatigue and energy are not simply two opposing sides of the same construct. Therefore, researchers should be mindful of the possible differences between fatigue and energy when selecting measures for research studies and when reporting findings. These two constructs need further refinement in theory and measurement to facilitate future research and to develop effective intervention strategies for reducing fatigue and low energy in patient populations with high prevalence. Finally, additional research is needed on the relationship between fatigue and energy in order to understand possible differences and clinical implications for interventions and quality of life across populations.

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References

Aouizerat BE, Gay CL, Lerdal A, Portillo CJ, Lee KA. Lack of energy: An important and distinct component of HIV-related fatigue and daytime function (in press). J Pain and Symptom Management. 2012

Barroso J, Hammill BG, Leserman J, Salahuddin N, Harmon JL, Pence BW. Physiological and psychosocial factors that predict HIV-related fatigue. AIDS Behav. 2010; 14:1415–1427. [PubMed: 20352317]

Bennett RM, Russell J, Cappelleri JC, Bushmakin AG, Zlateva G, Sadosky A. Identification of symptom and functional domains that fibromyalgia patients would like to see improved: A cluster analysis. BMC Musculoskeletal Disorders. 2010; 11:134. [PubMed: 20584327]

Bond, TG.; Fox, CM. Applying the Rasch model: Fundamental Measurement in the Human Sciences. Mahawah, New Jersey: Lawrence Erlabum Associates; 2001.

Bond, TG.; Fox, CM. Applying the Rasch Model: Fundamental Measurement in the Human Sciences. 2nd ed.. Mahwah, New Jersey: Lawrence Erlbaum Associates; 2007.

Borge CR, Wahl AK, Moum T. Association of breathlessness with multiple symptoms in chronic obstructive pulmonary disease. Journal of Advanced Nursing. 2010; 66:2688–2700. [PubMed: 20825511]

Chambers MJ, Docktor B. Fatigue scale lacks adequate validation. Psychiatry Research. 1993; 46:207–208. [PubMed: 8483979]

Dimsdale JE, Ancoli-Israel S, Elsmore TF, Gruen W. Taking fatigue seriously: I. Variations in fatigue sampled repeatedly in healthy controls. Journal of Medical Engineering & Technology. 2003; 27:218–222. [PubMed: 12936048]

Henderson M, Safa F, Easterbrook P, Hotopf M. Fatigue among HIV-infected patients in the era of highly active antiretroviral therapy. HIV Medicine. 2005; 6:347–352. [PubMed: 16156883]

Hofman M, Ryan JL, Figueroa-Moseley CD, Jean-Pierre P, Morrow GR. Cancer-related fatigue: The scale of the problem. Oncologist. 2007; 12(Suppl 1):4–10. [PubMed: 17573451]

Jason L, Benton M, Torres-Harding S, Muldowney K. The impact of energy modulation on physical functioning and fatigue severity among patients with ME/CFS. Patient Education and Counseling. 2009; 77:237–241. [PubMed: 19356884]

Jenkin P, Koch T, Kralik D. The experience of fatigue for adults living with HIV. Journal of Clinical Nursing. 2006; 15:1123–1131. [PubMed: 16911053]

Kottorp A, Bernspang B, Fisher AG. Activities of daily living in persons with intellectual disability: Strengths and limitations in specific motor and process skills. Australian Occupational Therapy Journal. 2003; 50:195–204.

Krupp L. Fatigue is intrinsic to multiple sclerosis (MS) and is the most commonly reported symptom of the disease. Multiple Sclerosis. 2006; 12:367–368. [PubMed: 16900749]

Krupp LB, Alvarez LA, LaRocca NG, Scheinberg LC. Fatigue in multiple sclerosis. Archives of Neurology. 1988; 45:435–437. [PubMed: 3355400]

Lee KA. The author replies. Psychiatry Research. 1993; 46:209–210.

Lee KA, Hicks G, Nino-Murcia G. Validity and reliability of a scale to assess fatigue. Psychiatry Research. 1991; 36:291–298. [PubMed: 2062970]

Lee KA, Lentz MJ, Taylor DL, Mitchell ES, Woods NF. Fatigue as a response to environmental demands in women's lives. Image Journal of Nursing Scholarship. 1994; 26:149–154.

Lee KA, Portillo CJ, Miramontes H. The fatigue experience for women with human immunodeficiency virus. Journal of Obstetric, Gynecologic, and Neonatal Nursing. 1999; 28:193–200.

Lerdal A. A concept analysis of energy. Its meaning in the lives of three individuals with chronic illness. Scandinavian Journal of Caring Science. 1998; 12:3–10.

Lerdal A. A theoretical extension of the concept of energy through an empirical study. Scandinavian Journal of Caring Science. 2002; 16:197–206.

Lerdal A, Bakken LN, Kouwenhoven SE, Pedersen G, Kirkevold M, Finset A, Kim HS. Poststroke fatigue – A review. Journal of Pain and Symptom Management. 2009; 38:928–949. [PubMed: 19811888]

Lerdal A, Gay CL, Aouizerat BE, Portillo CJ, Lee KA. Patterns of morning and evening fatigue among adults with HIV/AIDS. Journal of Clinical Nursing. 2011; 20:2204–2216. [PubMed: 21752119]

Linacre JM. Optimizing rating scale category effectiveness. Journal of Applied Measurement. 2002; 3:85–106. [PubMed: 11997586]

Linacre, JM. Optimizing rating scale category effectiveness. In: Smith, EV.; Smith, RM., editors. Introduction to Rasch Measurement: Theory, Models and Applications JAM Press Publisher. Maple Grove; 2004. p. 258-278.

Linacre, JM. [Retreived June 2010] Winsteps – Rasch Model computer program. Version 3.69.1.16. 2010. ed. Available from: URL: www.winsteps.com

Mantel N. Chi square tests with one degree of freedom: Extensions of the Mantel Haenszel procedure. Journal of American Statistical Association. 1963; 58:690–700.

Mantel N, Haenzel W. Statistical aspects of the analysis of data from retrospective studies of disease. Journal of the Natlional Cancer Institute. 1959; 22:719–748.

Marcellin F, Preau M, Ravaux I, Dellamonica P, Spire B, Carrieri MP. Self-reported fatigue and depressive symptoms as main indicators of the quality of life (QOL) of patients living with HIV and Hepatitis C: Implications for clinical management and future research. HIV Clinical Trials. 2007; 8:320–327. [PubMed: 17956833]

Meek PM, Nail LM, Barsevick A, Schwartz AL, Stephen S, Whitmer K, Beck SL, Jones LS, Walker BL. Psychometric testing of fatigue instruments for use with cancer patients. Nursing Research. 2000; 49:181–190. [PubMed: 10929689]

Miaskowski C, Lee K, Dunn L, Dodd M, Aouizerat BE, West C, Paul SM, Cooper B, Wara W, Swift P. Sleep wake circadian activity rhythm parameters and fatigue in oncology patients before the initiation of radiation therapy. Cancer Nursing. 2011; 34:255–268. [PubMed: 21252646]

Pallant JF, Tennant A. An introduction to the Rasch measurement model: An example using the Hospital Anxiety and Depression Scale (HADS). British Journal of Clinical Psychology. 2007; 46:1–18. [PubMed: 17472198]

Pence BW, Barroso J, Leserman J, Harmon JL, Salahuddin N. Measuring fatigue in people living with HIV/AIDS: Psychometric characteristics of the HIV-related fatigue scale. AIDS Care. 2008; 20:829–837. [PubMed: 18608084]

Petersson I, Lilja M, Hammel J, Kottorp A. Impact of home modification services on ability in everyday life for people ageing with disabilities. Journal of Rehabilitation Medicine. 2008; 40:253–260. [PubMed: 18382820]

Raiche G. Critical eigenvalue sizes in standardized residual prinicipal component analysis. Rasch Measurement Transactions. 2005; 19:1012.

Schaefer KM. Sleep disturbances and fatigue in women with fibromyalgia and chronic fatigue syndrome. Journal of Obstetric, Gynecologic, & Neonatal Nursing. 1995; 24:229–233.

Siegert RJ, Tennant A, Turner-Stokes L. Rasch analysis of the Beck Depression Inventory-II in a neurological rehabilitation sample. Disability and Rehabilitation. 2010; 32:8–17. [PubMed: 19925272]

Smith AB, Rush R, Fallowfield LJ, Velikova G, Sharpe M. Rasch fit statistics and sample size considerations for polytomous data. BMC Medical Research Methodology. 2008; 8:33. [PubMed: 18510722]

Smith, RM.; Miao, CY. Assessing unidimensionality for Rasch measurement. In: Wilson, M., editor. Objective Measurement: Theory into Practice. Ablex, Greenwich; 1994.

Smith RM, Schumacker RE, Bush MJ. Using item mean squares to evaluate fit to the Rasch model. Journal of Outcome Measurement. 1998; 2:66–78. [PubMed: 9661732]

Spector, PE. Summated Rating Scale Construction: An Introduction. Beverly Hills and London: Sage Publications; 1992.

Voss JG. Predictors and correlates of fatigue in HIV/AIDS. Journal of Pain and Symptom Management. 2005; 29:173–184. [PubMed: 15733809]

Wolfe EW, Smith EV Jr. Instrument development tools and activities for measure validation using Rasch models: Part I – instrument development tools. Journal of Applied Measurment. 2007a; 8:97–123.

Wolfe EW, Smith EV Jr. Instrument development tools and activities for measure validation using Rasch models: Part II – validation activities. Journal of Applied Measurment. 2007b; 8:204–234.

Wright, BD.; Masters, GN. Rating Scale Analysis: Rasch Measurement. Chicago: MESA Press; 1982.

Wright, BD.; Stone, MH. Best Test Design. Chicago: MESA Press; 1979.

Table 1

Sample demographics, clinical characteristics, and mean Fatigue and Energy Scale scores

	N	Mean (SD) or n (%)	Morning Fatigue (n=99[a])	Evening Fatigue (n=101[a])	Morning Energy (n=99[a])	Evening Energy (n=101[a])
Age in years (range 20–66)	102	38.2 (7.7)				
< 40 years		58 (57%)	33.0 (20.0)	47.1 (20.5)	40.5 (19.6)	35.1 (20.6)
≥ 40 years		44 (43%)	33.2 (22.4)	52.7 (19.5)	40.4 (21.3)	33.2 (22.4)
Race/Ethnicity	102					
African-American		59 (58%)	33.2 (21.8)	45.8 (20.4)	39.2 (21.1)	33.9 (21.4)
Caucasian		29 (28%)	36.8 (21.7)	60.3 (17.9)[b]	41.5 (20.1)	34.4 (20.0)
Hispanic/Latina		14 (14%)	25.1 (14.7)	43.4 (16.3)	43.4 (17.9)	32.7 (14.4)
Education	102					
Some high school or less		35 (34%)	34.8 (19.7)	47.4 (21.7)	34.8 (17.7)[c]	28.4 (15.2)[c]
Completed high school or more		67 (66%)	32.1 (21.8)	50.6 (19.4)	43.4 (21.0)[c]	36.6 (21.7)[c]
Employment	102					
Unemployed		88 (86%)	32.8 (21.3)	49.0 (19.7)	40.4 (20.0)	33.7 (20.2)
Employed (full-time, part-time, or self-employed)		14 (14%)	34.7 (19.9)	52.7 (23.4)	40.8 (22.6)	34.7 (19.3)
Annual income	102					
<$10,000		76 (75%)	30.2 (20.1)[c]	45.9 (18.5)[c]	39.7 (20.6)	33.1 (20.2)
≥$10,000		26 (25%)	41.6 (21.8)[c]	60.0 (21.5)[c]	42.7 (19.5)	35.9 (19.7)
Living with adult partner?	101[a]					
No		61 (60%)	31.5 (19.0)	46.2 (19.8)	38.9 (20.9)	31.7 (21.0)
Yes		40 (40%)	35.4 (23.9)	54.2 (20.0)	42.0 (19.0)	36.7 (17.9)
Any children? (range 0 –4)	99[a]					
No		68 (69%)	31.1 (22.0)	51.2 (20.1)	41.3 (21.4)	34.5 (21.1)
Yes		31 (31%)	38.3 (18.4)	46.3 (21.1)	37.3 (16.8)	32.9 (18.8)
Years since HIV diagnosis	93[a]	5.0 (3.4)				
(range 1 month – 15 years)						
< 5 years		50 (54%)	30.9 (20.6)	48.2 (19.6)	36.8 (20.1)	33.1 (19.3)

	N	Mean (SD) or n (%)	Morning Fatigue (n=99[a])	Evening Fatigue (n=101[a])	Morning Energy (n=99[a])	Evening Energy (n=101[a])
≥ 5 years		43 (46%)	36.9 (20.7)	53.2 (19.5)	42.1 (19.6)	33.5 (18.3)
CD4 T-cell count, cells/mm^3	79[a]	341 (241)				
(range 4 – 974)						
< 200[d]		26 (33%)	33.0 (17.4)	53.4 (19.0)	40.6 (17.5)	35.1 (22.1)
≥ 200		53 (67%)	34.0 (21.7)	49.7 (21.1)	39.9 (21.1)	33.8 (19.2)
Total Sample	102		33.1 (21.0)	49.5 (20.2)	40.4 (20.3)	33.8 (20.0)

[a]smaller sample size due to missing data;

[b]significantly higher than the other two groups;

[c]these two groups differ significantly ($p<.05$)

[d]participants with CD4 < 200 cells/mm^3 qualify for a diagnosis of AIDS

Table 2

Sample item format for the Lee Fatigue and Energy Scales including item difficulty estimates generated from the Rasch analysis (logits)

Sample fatigue items			
not at all drowsy	____________________________	extremely drowsy	(52.36)
not at all fatigued	____________________________	extremely fatigued	(51.03)
not at all exhausted	____________________________	extremely exhausted	(48.32)
Sample energy items			
not at all energetic	____________________________	extremely energetic	(51.33)
not at all efficient	____________________________	extremely efficient	(48.40)

Full scales available elsewhere (Lee et al., 1991).

Table 3

Overview of the analytic process for evaluating different aspects of validity

Step	Aspect of validity measured	Statistical Approach and Criteria	Fatigue Scale Results	Energy Scale Results
1	**Rating scale functioning:** Does the rating scale function consistently across items? (substantive validity)	• Each category should have a minimum of 10 observations. • Average measures for each category on each item should advance monotonically • *z*-values < 2.0 for outfit mean square *(MnSq)* values in step category calibrations[a]	• Each category was observed ≥10 times • All items met criteria	• Categories 8, 9, and 10 were ordered illogically (10, 8 , 9) • When 8, 9, 10 were collapsed into a single category, all items met criteria.
2	**Internal scale validity:** Do item responses match expected responses from the Rasch model? (content validity)	Item goodness-of-fit statistics • *MnSq* values between 0.7 and 1.3[b]	• All items met criterion	• All items met criterion
3	**Internal scale validity:** Is the scale unidimensional? (structural validity)	Principal component analysis • ≥ 50% of total variance explained by first component (fatigue/energy)[c]	• First component explained 52.1% of total variance	• First component explained 63.5% of total variance
4	**Differential item functioning** (DIF): Are item difficulty calibrations stable in relation to relevant variables?[d] (generalizability validity)	Mantel-Haenszel statistics • $p < .01$ with Bonferroni correction[e]	• Education: #13 • Time of day: #14, 18	• Education: #8
5	**Time of day effects:** Are morning and evening ratings correlated but different? (generalizability validity)	Pearson correlations and paired t-test • $r > .30$ • Evening > Morning (fatigue) • Morning > Evening (energy)	• $r = .38$ • Evening > Morning ($p < .001$)	• $r = .22$ • Morning > Evening ($p < .05$)
6	**Subscale correlations:** Are the Fatigue and Energy subscales correlated? (structural validity)	Pearson correlations • $r > .30$	**Fatigue and Energy Scale Results** • Morning $r = -0.31$, $p < .01$ • Evening $r = 0.05$, not significant	

[a]Linacre 2002;

[b]Smith et al. 1998;

[c]Linacre 2010;

[d]DIF variables evaluated: age, education, employment, income, partner, children, years since HIV diagnosis, CD4 count, and time of day;

[e]Mantel 1963