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Subjective Ratings of Fatigue and Vigor in Adults With Hearing Loss Are Driven by Perceived Hearing Difficulties Not Degree of Hearing Loss

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Abstract

Objectives: Anecdotal reports and qualitative research suggests that fatigue is a common, but often overlooked, accompaniment of hearing loss which negatively affects quality of life. However, systematic research examining the relationship between hearing loss and fatigue is limited. In this study, the authors examined relationships between hearing loss and various domains of fatigue and vigor using standardized and validated measures. Relationships between subjective ratings of multidimensional fatigue and vigor and the social and emotional consequences of hearing loss were also explored.

Design: Subjective ratings of fatigue and vigor were assessed using the profile of mood states and the multidimensional fatigue symptom inventory-short form. To assess the social and emotional impact of hearing loss participants also completed, depending on their age, the hearing handicap inventory for the elderly or adults. Responses were obtained from 149 adults (mean age = 66.1 years, range 22 to 94 years), who had scheduled a hearing test and/or a hearing aid selection at the Vanderbilt Bill Wilkerson Center Audiology clinic. These data were used to explore relationships between audiometric and demographic (i.e., age and gender) factors, fatigue, and hearing handicap scores.

Results: Compared with normative data, adults seeking help for their hearing difficulties in this study reported significantly less vigor and more fatigue. Reports of severe vigor/fatigue problems (ratings exceeding normative means by ±1.5 standard deviations) were also increased in the study sample compared with that of normative data. Regression analyses, with adjustments for age and gender, revealed that the subjective percepts of fatigue, regardless of domain, and vigor were not strongly associated with degree of hearing loss. However, similar analyses controlling for age, gender, and degree of hearing loss showed a strong association between measures of fatigue and vigor (multidimensional fatigue symptom inventory-short form scores) and the social and emotional consequences of hearing loss (hearing handicap inventory for the elderly/adults scores).

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Conclusions: Adults seeking help for hearing difficulties are more likely to experience severe fatigue and vigor problems; surprisingly, this increased risk appears unrelated to degree of hearing loss. However, the negative psychosocial consequences of hearing loss are strongly associated with subjective ratings of fatigue, across all domains, and vigor. Additional research is needed to define the pathogenesis of hearing loss-related fatigue and to identify factors that may modulate and mediate (e.g., hearing aid or cochlear implant use) its impact.

Keywords

Adults; Effort; Fatigue; Hearing disability; Hearing handicap; Hearing loss; Psychosocial consequences; Quality of life

INTRODUCTION

Feelings of fatigue are something most people have experienced at some point in their lives. Fatigue is often described subjectively as a mood or feeling of weariness, tiredness, or lack of energy (Tiesinga et al. 1996; O'Connor 2004). Everyday fatigue is a normal, and common, consequence of sustained and demanding physical or mental work. This type of fatigue tends to resolve quickly with breaks or rest and has minimal negative effects on quality of life. For some individuals, however, feelings of fatigue are more frequent, severe, and can be brought about by everyday activities (e.g., self-care, trying to understand people talking). Fatigue of this type can have significant negative effects on quality of life. Severe fatigue and feelings of low energy (vigor deficits) are common among individuals suffering from a wide range of chronic health issues, such as cancer, diabetes, and multiple sclerosis (Evans & Wick-strom 1999; Curt 2000; Flechtner & Bottomley 2003; Hardy & Studenski 2010). The consequences of this sustained and severe fatigue can be significant. Fatigued adults in the workplace are less productive and more prone to accidents (Ricci et al. 2007). Fatigued individuals have trouble maintaining attention and concentration; processing speed is reduced and decision-making abilities are impaired (van der Linden et al. 2003; Bryant et al. 2004; DeLuca 2005). Older adults suffering from fatigue are less active, more socially isolated, less able to monitor their own self-care, and more prone to depression than nonfatigued adults (Amato et al. 2001; Johnson 2005; Eddy & Cruz 2007).

Communication difficulties resulting from hearing loss can, in some cases, also have serious consequences, including a reduction in perceived quality of life, depression, increased stress, and impaired cognitive function (Mulrow et al. 1990; Dalton et al. 2003; McCoy et al. 2005; Chia et al. 2007). Interestingly, many of these issues are similar to the cognitive (e.g., reduced processing speed) and psychosocial (e.g., social isolation and depression) consequences commonly associated with fatigue. However, the relationship between hearing loss and fatigue has, until recently, received relatively little systematic research attention.

Anecdotal reports and qualitative research have long suggested that fatigue is a common accompaniment of hearing loss that negatively affects quality of life. Consider this anecdotal report: "I crashed. This letdown wasn't the usual worn-out feeling after a long day. It was pure exhaustion, the deepest kind of fatigue…. The only cause of my fatigue I could identify was the stress of struggling to understand what those around were saying…" (Copithorne

2006). Qualitative and objective research provides support for these anecdotal reports (Hetu et al. 1988; Backenroth & Ahlner 2000; Hornsby 2013; Hornsby et al. 2014) and suggests that the consequences of fatigue for persons with hearing loss can be significant (Kramer et al. 2006; Nachtegaal et al. 2009).

For example, Hetu et al. (1988) interviewed adults with hearing loss about hearing-related issues at work, strategies for coping with these issues, and their consequences. Respondents noted that a common coping mechanism was to maintain a high level of concentration and attention for auditory signals. This need for sustained concentration and attention led to increased feelings of stress, tension, and fatigue. The fatigue resulting from their hearing difficulties and coping strategies was such that some participants reported they were "…too tired for normal activities" after leaving work. A similar finding was reported by Backenroth and Ahlner (2000). Kramer et al. (2006) found workers with hearing loss were more likely to take sick leave due to complaints of "fatigue, strain, and burnout" than workers without hearing loss doing the same or similar jobs—highlighting the functional impact of increased stress and fatigue on adults with hearing loss.

In addition to asking about subjective percepts, Hornsby (2013) used objective measures to quantify fatigue resulting from sustained speech processing demands. Specifically, fatigue was defined objectively as a *decrease in task performance* over the duration (approximately 45 min) of a cognitively demanding dual task. Participants listened, with and without hearing aids, to strings of words in noise and repeated back each word as it was presented. During the task, they held the last five words in memory and waited for a visual marker on a computer screen. When the marker appeared participants would press a button, providing a measure of response speed and then repeat back the last five words.

Whether listening with or without hearing aids, subjective ratings suggested the task was fatiguing. However, there was no objective evidence of fatigue (i.e., word recognition, word recall, and visual reaction times remained stable over time) when listening with hearing aids. In contrast, when listening without hearing aids (unaided), word recognition and recall remained stable but visual reaction times systematically slowed. This is consistent with the idea that the stress and strain experienced by adults trying to understand speech in difficult conditions, particularly when listening without hearing aids, increases susceptibility to fatigue.

Despite the apparent link between hearing loss and fatigue, empirical research specifically examining this relationship has been limited. Hornsby et al. (2014) were the first to use a standardized and validated measure of fatigue, the PedsQL Multidimensional Fatigue Scale (Varni et al. 2002), to assess self-reported perceptions of fatigue in a diverse group of children with hearing loss (CHL). The PedsQL Multidimensional Fatigue Scale is a generic tool designed to assess multiple fatigue domains (general, sleep/rest, and cognitive fatigue) and provide a composite/total fatigue score. Across all domains, and the composite score, the CHL reported more fatigue than an age-matched control group of children without hearing loss. Importantly, the magnitude of the reported fatigue was substantial. CHL reported more fatigue than children with several other chronic health conditions (e.g., cancer, rheumatoid arthritis, diabetes).

In summary, persons with hearing loss appear to be at increased risk for fatigue, potentially due to their hearing loss-related difficulties processing auditory signals, including speech. There have, however, been no studies using standardized measures to examine fatigue in adults with hearing loss. In this study, we use two, validated, generic fatigue scales to examine relationships between audiometric factors (degree of hearing loss) and the subjective percepts of fatigue and vigor. Relationships among fatigue, vigor, and the social and emotional consequences of hearing loss are also explored.

MATERIALS AND METHODS

Participants and Procedures

Participants were recruited from a pool of adults scheduled for a hearing evaluation or a hearing evaluation/hearing aid selection at the Vanderbilt Bill Wilkerson Center Audiology clinic between September 2011 and September 2012. All individuals calling to schedule an evaluation during the study period were eligible. Potential participants were mailed a questionnaire asking about age and gender, two self-report measures of fatigue, and a measure of hearing handicap (all measures are described below). Participants were asked to bring the completed questionnaires with them to their appointment. Study procedures were in compliance with the Office of Human Resource Protection requirements. Data were obtained from the returned questionnaires and clinical records review and did not require direct contact with participants.

A total of 153 participants completed at least some portion of the study questionnaires. Due to administrative errors, questionnaires were not sent out to every eligible participant during the study period, thus the true response rate is unknown. Of the participants who completed the questionnaire, two respondents did not have audiometric testing conducted during their clinical visit and two respondents had no measurable hearing in one ear. These four participants were excluded from further analyses, resulting in a study sample size of 149 (59% males) with a mean age of 66.1 years (standard deviation: 15.5 years and range: 22 to 94 years).

Medical records were reviewed to obtain audiometric threshold data and determine type of hearing loss. Details regarding hearing aid ownership and use were not obtained as these data are stored in a separate electronic database that is not linked to the participant’s medical record. However, we assume that a portion of respondents were current hearing-aid users. Audiometric data included pure-tone air conduction thresholds for each ear at frequencies of 250, 500, 1000, 2000, and 4000 Hz. Type of hearing loss (sensorineural, conductive, or mixed) was determined based on tympanometry and the presence/absence of an air-bone gap. The vast majority of respondents had sensorineural hearing losses (n = 276 ears), approximately 6% of ears (n=17) had a mixed component while less than 2% (n = 5) of ears tested had pure conductive losses. Degree of hearing loss varied widely in our sample with better ear pure-tone average (PTA; average thresholds at 500, 1000, and 2000 Hz) air conduction thresholds ranging from 5 to 95 dB HL (mean = 36.7 dB HL; standard deviation = 17.7 dB). Figure 1 shows a histogram of the better ear PTAs of the study participants.

Measures

Subjective Fatigue •—Subjective fatigue was assessed using the profile of mood states (POMS; McNair et al. 1971) and the multidimensional fatigue symptom inventory-short form (MFSI-SF; Stein et al. 2004). The POMS is a 65-item measure designed to assess multiple mood states, including tension, depression, anger, confusion, fatigue, and vigor. It has been used extensively to assess fatigue and vigor in individuals with a wide range of chronic health conditions, such as cancer, rheumatoid arthritis, multiple sclerosis, and chronic dialysis (Wolcott et al. 1988; Petajan et al. 1996; Hewlett et al. 2007; Minton & Stone 2009) and has good psychometric properties (e.g., internal reliability, content and construct validity, and test–retest reliability; McNair & Heuchert 2010). In this study, only 15 items used to derive the fatigue and vigor subscales were administered. Respondents use a five-point scale to rate how well each item describes their feelings "during the PAST WEEK, including today" (0: not at all, 1: a little, 2: moderately, 3: quite a bit, and 4: extremely). Scores for each item are summed to obtain an overall score for each subscale. Following the recommended scoring protocol (McNair & Heuchert 2010), if one or two items in a subscale are missing, a prorated score is computed by multiplying the mean response from the nonmissing items by the total number of items in the subscale and rounding to the nearest integer. For subscales with more than two items missing, no subscale score is imputed. Subscale scores can range from 0 to 28 or 0 to 32 for the fatigue and vigor subscales, respectively, with higher scores indicating higher levels of fatigue and vigor.

We chose the POMS as a measurement tool because it allows us to compare our results with normative data. POMS normative data are based on responses from individuals recruited via local church and community groups and include a sample of college-aged adults (18 to 24 years; n = 856), the general adult population (18 to 94 years; n = 400), and a geriatric population (55 to 94 years; n = 170; Nyenhuis et al. 1999; McNair & Heuchert 2010). Given that participants included in the normative sample were recruited from the general population it is likely that at least some of these individuals also had hearing loss. However, a primary difference between our participants and those used to derive normative data is that *all* of our participants were actively seeking help for hearing difficulties.

The POMS provides a valid unidimensional measure of general fatigue (e.g., a general feeling of being tired or worn out) and vigor (a general feeling of being energetic, alert, or vigorous). Additional dimensions of fatigue were assessed using the MFSI-SF. The MFSI-SF is a 30-item measure which has been used, primarily, in the assessment of cancer-related fatigue. It assesses four dimensions of fatigue (general, physical, emotional, and mental) and the construct of vigor, each with six test items. Like the fatigue and vigor subscales of the POMS, the MFSI-SF general fatigue and vigor subscales query respondents about general feelings of tiredness (e.g., I am worn out) and energy (e.g., I feel lively). The physical fatigue sub-scale assesses feelings of muscle or body weakness (e.g., My legs feel weak). The mental fatigue subscale assesses mental abilities, such as memory, attention, and concentration, which may be degraded in a fatigued state (e.g., I am unable to concentrate). Finally, the emotional fatigue subscale queries respondent's feelings of stress, tension, and depression (e.g., I am distressed).

Like the POMS, the MFSI-SF has good psychometric properties (Stein et al. 2004). Respondents rate how “true” each item (e.g., I am worn out) has been for them in the past 7 days using the same five-point scale as the POMS. If one or two items in a subscale were missing, a prorated score was computed as described for the POMS scale. Scores are summed for each subscale and thus can range from 0 to 24 with higher numbers reflecting more fatigue and vigor. In addition, an estimate of total (or composite) fatigue can be derived by summing the scores on the fatigue subscales and subtracting the vigor score. A total fatigue score is not computed if more than two items are missing for any one of the MFSI subscales. The total fatigue score can range from −24 to 96, again with higher numbers reflecting greater fatigue. Normative data are not available for the MFSI-SF.

Measure of Hearing Handicap •—Social and emotional consequences of hearing loss were assessed using the hearing handicap inventory for the elderly (HHIE; Ventry & Weinstein 1982) or adults (HHIA; Newman et al. 1990). The HHIE was completed by respondents ≥65 years while those younger than 65 years completed the HHIA. The HHIE and HHIA (HHIE/A) each contain 25 items and assesses social/situational (e.g., “Does a hearing problem cause you to avoid groups of people?”) and emotional (e.g., “Does a hearing problem make you irritable?”) problems experienced by an individual as a result of their hearing loss. Respondents select yes, sometimes, or no (4, 2, or 0 points) for each item and responses are summed to generate an emotional, social, and total score. Scores can range from minimum of 0, reflecting no perceived handicap, to a maximum of 48, 52, or 100 for the social, emotional, and total score, respectively, with higher scores indicating a greater negative effect of hearing loss on the individual. Participants with missing responses to any HHIE/A item were excluded from analyses. The HHIE/A have been widely used in audiologic research. Reports from the literature suggest that they have good internal consistency and test–retest reliability (Ventry & Weinstein 1982; Weinstein et al. 1986; Newman et al. 1990).

Statistical Analysis

The primary variables of interest are all measured on a continuous scale. The one exception (discussed below) is a dichotomous variable for describing severe fatigue and severely low vigor. These variables are based on cutpoints suggested in the POMS normative data (McNair & Heuchert 2010).

Comparisons with POMS Normative Data and Between MFSI-SF Domains •— Our first analyses examined the question of whether fatigue or vigor, as measured via the POMS, differed between our sample of adults seeking help for hearing difficulties and normative data. We used a series of one sample *t* tests to compare differences in POMS fatigue and vigor ratings between our samples and normative data. We were also interested in whether our sample, compared with normative data, had a higher prevalence of severe fatigue or severely low vigor. Severe fatigue was operationally defined as ratings that were ≥1.5 standard deviations above the normative mean (fatigue scores ≥ 15). Severely low vigor was defined as ratings that were ≤1.5 standard deviations below the normative mean (vigor scores ≤12). Based on normative data, approximately 7% of fatigue and vigor scores would be expected to be at least 1.5 standard deviations above, or below, the mean scores (McNair

& Heuchert 2010). A prevalence ratio with corresponding 95% confidence intervals was calculated to compare our study population to the normative data.

Finally, we used MFSI-SF data to explore whether particular domains of fatigue or vigor were more problematic than others, for our sample of adults with hearing difficulty. For MFSI-SF fatigue domain scores, higher values indicate more problems. However, for vigor scores, the reverse is true—higher scores indicate fewer problems. Recall, all domains scores are based on responses to six-test items and can range from 0 to 24. To allow us to directly compare fatigue and vigor domains during cross-domain analyses, and for the regression analyses described below, MFSI-SF vigor scores were reverse coded so that higher scores indicate *more* problems. When discussing vigor findings in relation to these analyses, for clarity, we use the term "vigor deficit." A Friedman's ANOVA was used to examine differences in MFSI-SF domains (general, physical, emotional and mental fatigue, and vigor deficit). Differences between domain subscale scores were examined using a series of Wilcoxon signed ranks tests with a Bonferonni correction for increases in type 1 errors.

Examining Associations Between Objective and Subjective Hearing Difficulties and Fatigue •—Our second set of analyses examined whether (1) degree of hearing loss (better-ear PTA) was associated with subjective ratings of fatigue and vigor, and (2) self-reported hearing difficulties (HHIE/A scores) were associated with subjective ratings of fatigue and vigor. Only the MFSI-SF ratings were used in this set of analyses, as they allow us to specifically explore whether particular domains of fatigue or vigor are more likely to be associated with PTA or subjective hearing difficulty than other domains. MFSI-SF domain scores were not normally distributed (Shapiro–Wilk normality test; $p < 0.05$) with the exception of MFSI-SF vigor ($p = 0.34$), so multivariable quantile regression was used for all analyses. Unlike ordinary least squares regression, quantile regression estimates the median of the dependent variable instead of the mean without making normality and equal variance assumptions. Because fatigue and vigor ratings, as well as degree of hearing loss and hearing handicap, can vary with gender and age, we included these factors in the regression models (Ventry & Weinstein 1982; McNair & Heuchert 2010; Mitchell et al. 2011). In the second set of analyses examining associations between subjective hearing difficulty (HHIE/A score) and fatigue and vigor, better-ear PTA was also included in the regression models along with age and gender, given the well-known relationship between degree of hearing loss and hearing handicap (e.g., Weinstein & Ventry 1983).

In addition, because the predictor variables of age, degree of hearing loss, and hearing handicap were continuous, the linearity of the relationship between each predictor and the fatigue and vigor outcomes was assessed. Likelihood ratio tests were conducted to test the null hypothesis of no significant contribution from the nonlinear terms, which would suggest a simple linear relationship between the predictor and dependent variables. For variables indicating a statistically significant departure from linearity ($p < 0.05$), a restricted cubic spline with three knots was retained in the final regression model, otherwise a simple linear term was used. All analyses were conducted using the statistical analysis package R (R Core Team 2013). For all analyses, results suggest that age and degree of hearing loss could be modeled as simple linear variables. In contrast, hearing handicap demonstrated a nonlinear relationship with fatigue or vigor in some cases and was therefore modeled and reported as either simple linear or nonlinear, as appropriate.

RESULTS

Subjective Fatigue in Adults With Hearing Difficulties

We first examined whether the fatigue and vigor of adults with hearing difficulties differed from a comparable POMS normative sample. POMS normative data suggest that, on average, older adults (geriatric sample >55 years) report *less* fatigue and *more* vigor than college-aged adults and the general adult population (Nyenhuis et al. 1999). The majority of participants in this study were ≥55 years. We therefore compared the POMS fatigue and vigor scores from this subset (mean age =72.3 years; range: 55 to 94 years; n = 116) with the POMS geriatric norms (mean age = 68.1 years; range: 55 to 94 years; n = 170). Although the range of ages in both groups was the same, a one sample t test showed our group of adults with hearing loss were significantly older (4.2 years) than the normative group [$t(115) = 4.47$, $p < 0.001$, Cohen's $d = 0.41$].

Our subset of older adults had a mean, better ear, PTA of 38.9 dB HL (range: 8.3 to 95 dB HL). One sample t test results showed that adults with hearing difficulty in this study reported significantly less vigor {POMS mean vigor rating = 16.3 (standard deviation [SD] 7.8) versus 21.3 (SD = 6.0); $t(115) = 6.89$, $p < 0.001$, Cohen's $d = 0.64$} and slightly more fatigue, although the difference in POMS fatigue scores was not statistically significant (mean score = 6.9 [SD = 6.7]; POMS mean = 6.1 [SD = 5.4]; $t(115) = 1.33$, $p = 0.19$, Cohen's $d = 0.12$).

In addition to examining differences in mean fatigue and vigor ratings, we also examined differences in the relative occur-rence of *severe* fatigue (scores ≥ 15) and severely low vigor (scores ≤ 12) between groups. Our sample of older adults with hearing difficulty reported severe fatigue significantly more often than expected based on normative data {15% (n = 17) versus 7%, respectively; prevalence ratio = 2.08 (95% confidence intervals [CI]: 1.03–4.18); p = 0.037}. Severely low vigor was even more common in our population with 32% (n = 37) of our older adults reporting severely low vigor compared with 7% from the normative data (prevalence ratio = 4.52 [95% CI: 2.46–8.29]; $p < 0.001$).

Finally, we were interested in whether a particular domain of fatigue was more problematic than the other domains for adults with hearing difficulty. Given the linkage between increased cognitive processing demands and hearing loss (e.g., McCoy et al. 2005), we expected mental fatigue to be more problematic than other domains. Because we were not comparing scores to normative data for a geriatric population, we included all participants that had complete MFSI-SF data for a given sub-scale in these analyses (n = 146 to 148 depending on the subscale). Results from a Friedman's test revealed a statistically significant difference between MFSI-SF subscale scores ($X^2(4) = 222.2$; $p < 0.0001$). Consistent with the POMS data, pair wise comparisons using Wilcoxon signed ranks tests indicated that vigor deficit (reverse coded vigor scores) was significantly greater than any other subscale score ($p < 0.001$; Z's ranged from −8.27 to −9.89) even after Bonferonni correction for multiple tests (corrected p value of 0.05/10 = 0.005). In addition, general fatigue was significantly greater than any other fatigue domain (physical and emotional fatigue, $p < 0.001$ and mental fatigue, $p = 0.001$; $Z = -6.09$, -5.4, and -3.38, respectively). Likewise, mental fatigue was significantly greater than emotional ($p = 0.001$; $Z = -3.39$) and physical ($p = 0.001$; $Z = -3.40$) fatigue, while emotional and physical fatigue were nearly identical ($p = 0.78$; $Z = -0.28$). Mean MFSI-SF subscale scores are shown in Figure 2.

Effect of Degree of Hearing Loss on Fatigue and Vigor

A primary purpose of this study was to examine the common assumption that speech processing difficulties and the resultant increase in cognitive processing demands that accompany increased hearing loss, lead to problems with fatigue and vigor. In contrast to our initial hypothesis, results showed that degree of hearing loss was not significantly (all comparisons $p > 0.05$) associated with subjective ratings of fatigue or vigor. Table 1 shows results of the regression analyses. Only minimal changes in MFSI-SF ratings, regardless of domain, were observed. Changes in fatigue and vigor deficit subscale ratings ranged from −0.01 to 0.04 per one dB increase in better-ear PTA. A slightly larger change of 0.08 per one dB increase in better-ear PTA was observed for the total fatigue rating; however, this reflects the much larger range of that measure. These associations remain negligible even when considering clinically meaningful changes in thresholds. For example, a 10 dB increase in PTA is only associated with a 0.40-point increase (on a scale ranging from 0 to 24) in physical fatigue ($p = 0.08$). To ensure our choice of thresholds did not unduly influence our results, we replicated these analyses using a better-ear PTA of 1000, 2000, and 4000 Hz, as well as a better-ear PTA of 2000, 3000, and 4000 Hz. Results showed that, regardless of the frequencies used to determine PTA, degree of hearing loss was not associated with subjective ratings of fatigue or vigor (no change in beta coefficients and all comparisons $p > 0.05$; data not shown).

Hearing Handicap and Subjective Ratings of Fatigue and Vigor

Previous study (e.g., Hetu et al. 1988), and the comparison with POMS normative data described in this study, suggests a link between hearing difficulties and fatigue and vigor. However, our analysis of associations between hearing impairment, as quantified by PTA, and fatigue showed no such relationship. Here, we examine potential associations between psychosocial hearing difficulties, measured using the HHIE/A, and subjective ratings of fatigue and vigor. In contrast to our PTA analyses, psychosocial hearing difficulties were strongly associated with subjective ratings of fatigue and vigor. Specifically, regression results revealed significant associations between all HHIE/A scores (emotional, social, and total) and MFSI-SF ratings across all domains. Specific relationships are described below.

Associations Between HHIE/A Emotional Subscale Scores and MFSI-SF Ratings •—HHIE/A emotional subscale scores (range: 0 to 52) demonstrated a simple linear relationship with the general, physical and emotional MFSI subscale scores (range: 0 to 24), as well as the MFSI-SF Total score. After controlling for degree of hearing loss, age and gender, a one-point increase in the HHIE/A emotional subscale score was associated with a 0.16 (general), 0.10 (physical), and 0.18 (emotional)-point increase in subjective MFSI fatigue ratings (all $p < 0.05$; Table 2 and Fig. 3). The association between HHIE/A emotional scores and the MFSI-SF total score was also linear in nature but showed a substantially larger change (0.81-point increase per one-point increase in HHIE/A emotional score; $p = 0.003$; Table 2). However, this larger value reflects the much larger range of the total score (−24 to 96 points) and is thus not directly comparable with the observed changes in domain-specific ratings.

In contrast, the association between HHIE/A emotional scores and MFSI mental fatigue and vigor deficit (range: 0 to 24) showed a *nonlinear* relationship (Table 2 and Fig. 3). For these domains, there was no association at lower HHIE/A scores (e.g., below the median score of 16), while stronger associations were observed at higher scores. For example, for HHIE/A emotional scores ≥28 (the 75th percentile of our scores), a one-point increase in the HHIE/A emotional score resulted in a 0.32-point increase in mental fatigue ($p < 0.001$) and a 0.25-point increase in vigor deficit ratings ($p < 0.001$)—associations nearly twice as strong as for the other domains (Table 2).

Associations Between HHIE/A Social Subscale Scores and MFSI-SF Ratings •—In contrast, HHIE/A social subscale scores (range: 0 to 48) primarily demonstrated a *nonlinear* relationship with the MFSI scores. This included the general, emotional, and vigor domains, as well as the total fatigue rating. A simple linear relationship was only observed for the physical and mental fatigue domains. For these subscales, a one-point increase in the HHIE/A social subscale score resulted in a 0.08 (physical fatigue) and 0.20 (mental fatigue)-point increase in MFSI-SF ratings (both $p < 0.05$; Table 2).

In contrast, the *nonlinear* relationships again showed little to no association with MFSI-SF ratings at low HHIE/A social scores and much stronger associations at higher scores (e.g., HHIE/A social scores ≥26—the 75th percentile of our sample). For these higher scores, a one-point increase in the HHIE/A score resulted in 0.40 (vigor deficit), 0.42 (emotional), and 0.50 (general)-point increase in subjective MFSI fatigue ratings (all $p < 0.05$)—associations that are approximately two to six times stronger than for the mental and physical fatigue domains (Table 2 and Fig. 3). As in our analysis of HHIE/A social scores, a similar, but much stronger, nonlinear relationship was seen for the total fatigue score (Table 2 and Fig. 3), again reflecting the much larger range of the total score (range: −24 to 96).

Associations Between HHIE/A Total Scores and MFSI-SF Ratings •—Similar to HHIE/A social subscale scores, HHIE/A total scores primarily demonstrated a *nonlinear* relationship with the MFSI-SF domains. Simple linear relationships were only observed for the physical and emotional subscales. For these scales, a one-point increase in the HHIE/A total score resulted in a 0.05 (physical) and 0.10 (emotional)-point increase in subjective MFSI-SF fatigue ratings (all $p < 0.05$; Table 2).

As in our prior analyses, for subscale domains showing a *nonlinear* relationship (general and mental fatigue and vigor), there was little to no association at low HHIE/A scores while stronger associations were observed for higher scores. Likewise, for these domains, the associations observed at higher HHIE/A scores were again much stronger (1.6 to 4.8 times larger) than for the other domains showing linear associations (Table 2 and Fig. 3). A similar nonlinear relationship was seen for the MFSISF total score with no association at low HHIE/A scores and a strong association at higher scores (e.g., scores ≥54—the 75th percentile for our sample; $p < 0.001$; Table 2 and Fig. 3). Again, note that the magnitude of changes in the MFSI-SF total score, compared with domain-specific subscales, reflects the much larger range of the total score.

DISCUSSION

In this study, we used validated fatigue measures (the POMS and MFSI-SF) to quantify the subjective percept of fatigue and vigor in adults seeking help for their hearing difficulties. We also used these measures to explore associations between these measures and objective hearing difficulties (better ear PTA), as well as psychosocial hearing difficulties (HHIE/A scores). Three conclusions arose from this study and are discussed in more detail below: (1) adults seeking help for their hearing difficulties were more likely to report low energy (vigor deficit) and to a lesser extent increased fatigue than similarly aged adults in the general population, (2) there was no relationship between degree of hearing loss and subjective ratings of vigor or fatigue, and (3) subjectively measured hearing difficulty (HHIE/A scores) was strongly associated with all fatigue domains.

Our first conclusion was that, compared with POMS normative data, adults seeking help for their hearing difficulties were more likely to report low energy (vigor deficit) and to a lesser extent increased fatigue. While our sample was significantly older (72.3 years) than the normative data (68.1 years), we feel confounding by age is unlikely to have artificially inflated group differences. First, given that normative values for fatigue actually *decrease* with age, we might predict less fatigue for our respondents—not more as we found. Second, it is likely that at least some of the respondents in the normative group had hearing loss—potentially decreasing differences between our groups. Despite these issues, we still see significantly more fatigue and less vigor in our sample. In fact, severe fatigue was twice as high in our sample (prevalence ratio = 2.08; 95% CI: 1.03 to 4.18) and severely low vigor was more than four times as likely (prevalence ratio: 4.52; 95% CI: 2.46 to 8.29) compared with the normative sample. A more important concern may be that we do not know the general health status of the normative sample or our respondents—we were not able to collect information regarding other health conditions that may affect fatigue. Thus, it is possible that our sample may have had more fatigue-related health issues than respondents from the normative sample leading to higher levels of reported fatigue.

Fatigue and vigor ratings are generally highly and negatively correlated, with vigor decreasing as fatigue increases. However, validation studies using the POMS and MFSI-SF have shown these to be independent factors rather than a single bipolar factor (Stein et al. 1998, 2004; McNair & Heuchert 2010). POMS and MFSI-SF ratings of vigor are based on responses to items such as “cheerful, lively, relaxed, refreshed, energetic, calm, active, alert, full of pep, carefree, and vigorous.” While fatigue ratings are based on terms such as “pooped, worn out, fatigued, sluggish, run down, tired, listless, exhausted, weary, and bushed.” Our participants were more likely to describe themselves as less “refreshed” or “energetic” than more “weary” or “fatigued,” although the reason for this tendency is unclear.

Our second finding was that, despite increased complaints of severe fatigue and severely low vigor in our study population, there was no relationship between degree of hearing loss and these subjective ratings (Table 1). It is commonly assumed that reports of low energy and fatigue from persons with hearing loss are the result of the increased cognitive effort required to overcome deficits in hearing resulting from their hearing loss (Copithorne 2006; Edwards 2007; Zekveld et al. 2010; Hornsby 2013; Bess & Hornsby 2014). Given the mental effort required to complete cognitively challenging listening tasks generally increases in the presence of hearing loss (Rabbitt 1991; McCoy et al. 2005), we hypothesized that subjective fatigue would be positively (and vigor negatively) associated with degree of hearing loss. This was not the case, however, and suggests that the magnitude of hearing loss, per se, is not driving these complaints.

The lack of association between objective measures of health status (PTA in this case) and fatigue is a common finding in the fatigue literature (Leavitt & DeLuca 2010). The lack of systematic relationships between health characteristics (such as degree of hearing loss) and subjective fatigue may be that other factors moderate these associations. Ackerman (2011) suggests that subjective fatigue may be modulated by four general factors: (1) the cognitive effort required to complete a task (e.g., time on task, cognitive complexity, need for sustained attention), (2) baseline affective factors (e.g., depression, chronic fatigue syndrome), (3) transient affective factors (e.g., current mood and concerns), and (4) conative factors (e.g., past experiences with a given task/situation, interest and motivation to complete the task).

Even if degree of hearing loss were the same across participants, the impact of these other factors on subjective ratings of fatigue likely varies. For example, it is well known that speech recognition ability in persons with hearing loss varies widely, even when degree of hearing loss is similar (e.g., Hornsby et al. 2011). Thus given similar daily experiences, we might expect the cognitive effort, and potentially fatigue, of those with poorer speech processing abilities to be greater than those with better processing speech abilities. Unfortunately, we could not test this hypothesis. The only measure of speech recognition available from our sample was word recognition scores (Northwestern University Auditory Test No. 6) obtained as part of their clinical test battery. In general, performance on this test was very good (73% of participants had better ear scores ≥90% correct) resulting in ceiling effects which limited the utility of this information.

In addition, individual motivation and prior experiences also appear to influence fatigue onset and magnitude. Current models suggest the subjective percept of fatigue reflects a loss of motivation, or desire, to continue working on a task. Likewise motivation to continue physically or mentally challenging tasks is dependent, in part, on the importance of the task to the individual and their past experiences (Hockey 1997, 2011; van der Linden et al. 2003; van der Linden 2011). Specifically, fatigue resulting from sustained effort (e.g., attempting to understand speech in a noisy setting) is increased when (1) the task is considered important, (2) the task requires a high level of sustained mental effort, and (3) the reward for completing the task is low (Hockey 1997; Boksem & Tops 2008).

Consider how this could relate to individuals with hearing loss. Subjective reports suggest that persons with hearing loss must maintain higher levels of attention to auditory signals over an extended time in their work settings (e.g., Hetu et al. 1988). Despite this sustained mental effort, communication difficulties often remain potentially resulting in a low-reward situation (Kochkin 2000; Pichora-Fuller 2003; Kramer et al. 2006). This combination of high-effort/low-reward experiences may be common for some persons with hearing loss attempting to hear and understand in everyday settings. In our study, the effort needed to complete daily activities and the relative rewards for those efforts likely varied across participants, potentially moderating any effects of degree of loss on fatigue. Our study, however, was not designed to test this hypothesis.

Our final conclusion was that, although objective hearing difficulty (PTA) was not associated with fatigue or vigor deficit, a subjective measure of psychosocial hearing difficulty (HHIE/A scores) was strongly associated with all fatigue domains. Specifically, as the subjective percept of hearing difficulty (HHIE/A scores) increases, fatigue and vigor problems (MFSI-SF scores) also increase (Fig. 3). Furthermore, over half of these associations demonstrated a nonlinear dose–response, with fatigue and vigor problems only increasing at the higher levels of subjective hearing handicap. For example, when perceived handicap ranges from very low to mild–moderate handicap (e.g., HHIE total scores of 0 to 42) there are only minimal changes in fatigue or vigor as HHIE/A total scores increase (e.g., no more than a five-point change in MFSI-SF total scores; see Fig. 3, bottom right panel). However, as perceived hearing difficulties increase further (total scores >42) there is a concurrent, dramatic rise in subjective reports of fatigue and vigor problems. The reason for the nonlinear relationship between perceived hearing handicap and fatigue problems is unclear, but may suggest the impact of mild to moderate perceived hearing difficulties are focused, and transient, in nature. In other words, individuals reporting only mild–moderate perceived hearing difficulties may view those problems as specific to a given situation (e.g., difficulty understanding a spouse in a noisy setting), with little impact once the event is over. However, our results suggest a “threshold” of perceived hearing difficulties (i.e., HHIE/A scores ~42). Above this point, the impact is no longer transient in nature but has longer term effects, such as increased reports of fatigue and vigor problems (recall the MFSI asks about fatigue and vigor problems over the past week).

This finding, coupled with the lack of association between objective measures of hearing difficulties (PTA) and fatigue problems, highlights the importance of the *perception* of hearing difficulties. Recent study examining the general relationship among the motivation, task difficulty, perceived effort, and subjective fatigue also supports this idea. Earle et al. (2015) examined the relationship between subjective effort applied during a mentally demanding visual task and the change in fatigue after task completion as a function of motivation. Two groups of college students participated. Motivation was varied between groups by changing the task instructions (standard instructions/high motivation instructions). Subjective effort ratings increased systematically as task difficulty increased for both groups. However, fatigue increased with task difficulty (and effort) only for the high motivation group. This finding, coupled with the fact that the high motivation group tended to use “low-effort” strategies on a separate poststudy task, led the authors to conclude that fatigue was a consequence of the perceived effort applied on a task, not the difficulty of the task, per se. In our sample, we speculate that those with greater perceived hearing difficulties also experienced a perceived need for greater effort in their everyday listening situations—potentially increasing their risk for fatigue and vigor problems. Future study is needed to directly test this hypothesis.

LIMITATIONS

We acknowledge that some limitations exist in our study. First, the sample size was small (n = 153) which affects the precision of our modeling estimates. Second, although our results suggest a strong association between the psychosocial impact of hearing loss and subjective ratings of fatigue and vigor, the cross-sectional study design does not allow us to determine the direction of the relationship. Participants experiencing severe fatigue may be less able to deal effectively with the social and emotional issues resulting from their hearing loss—resulting in higher hearing handicap scores; or individuals that perceive substantial difficulties due totheir hearing loss (i.e., have high HHIE/A scores) may be more likely to become fatigued. Third, selection bias is possible: individuals with high levels of fatigue may not have sought a hearing evaluation at our clinic because of their fatigue. If hearing loss and hearing handicap are truly associated with fatigue, our results would reflect an underestimate of this association. This could have contributed to the null findings when examining associations between PTA and fatigue. Similarly, this selection bias combined with the small sample size may have reduced the power to detect nonlinear associations. We believe it is likely that many, if not all, of the linear associations observed may have demonstrated nonlinear associations if the sample size were larger and included more individuals with high levels of fatigue. Finally, there may be some residual confounding present in the associations we observed, such as psychosocial factors (e.g., depression) or other comorbidities. While these may affect subjective level of fatigue and either objective hearing loss or subjective hearing handicap, our study was not designed to identify these factors and the degree of confounding remains unclear. Future study is needed to clarify both the relationship between subjective hearing handicap and the influence of other potential confounders.

CONCLUSIONS

Individuals with hearing loss seeking help for their hearing difficulties have an increased risk of low vigor (feelings of low energy) and, to a lesser extent, subjective fatigue. Surprisingly, this increased risk appears unrelated to the degree of their hearing loss. However, a strong association between subjective ratings of social and emotional problems due tohearing difficulties (HHIE/A scores) and fatigue and vigor deficit was also observed, and was not specific for any one domain of fatigue. Given this strong association, and existing work highlighting the benefits of hearing rehabilitation strategies (e.g., hearing aids, cochlear implants, FM systems, etc.) for reducing perceived hearing handicap, future study examining the potential benefits of hearing rehabilitation strategies on reducing fatigue and vigor deficit are warranted.

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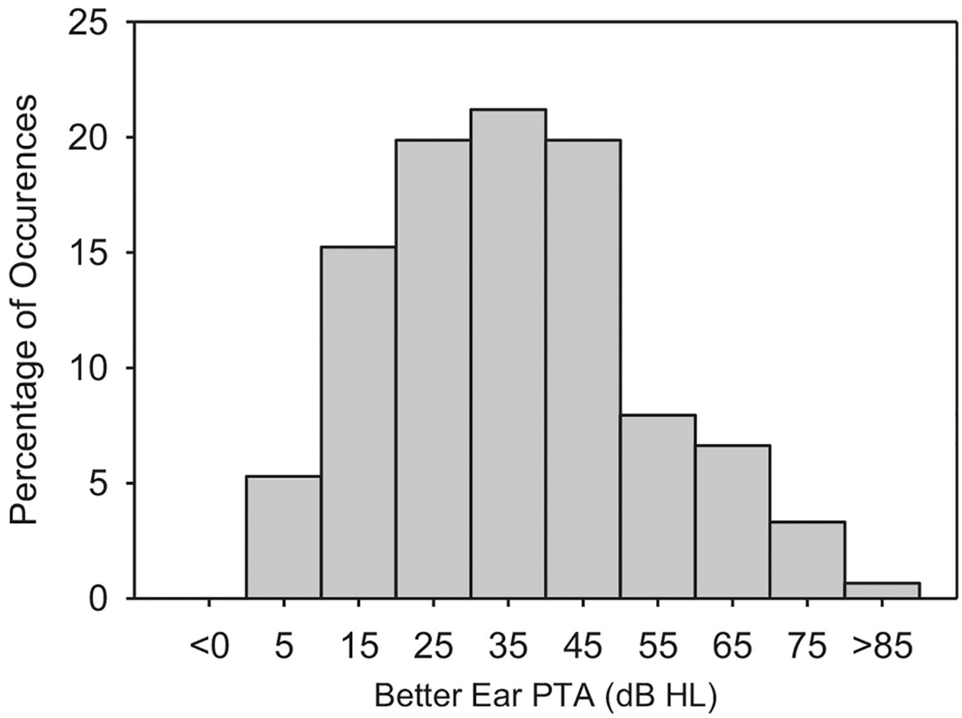

Fig. 1.

Histogram of better ear PTA (average threshold at 500, 1000, and 2000 Hz in a given ear) thresholds for our study participants. PTA indicates pure-tone average.

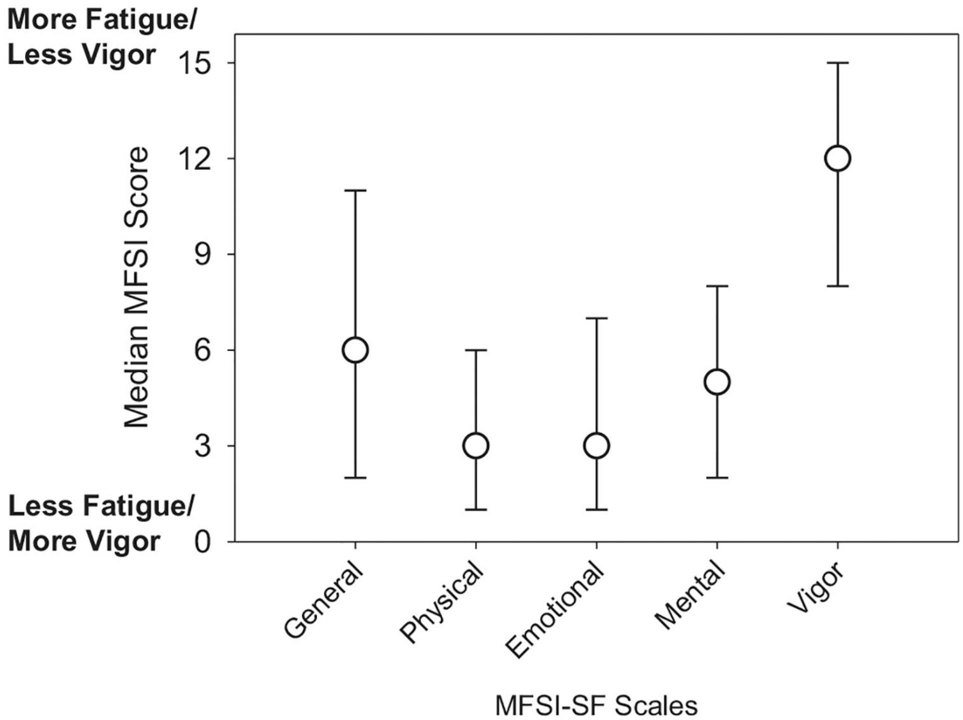

Fig. 2.

Median MFSI-SF subscale scores. Vigor data were reverse scored so that a larger number reflects more problems, consistent with the other fatigue domains. Error bars show the 25th and 75th percentile range of scores. MFSI-SF indicates multidimensional fatigue symptom inventory-short form.

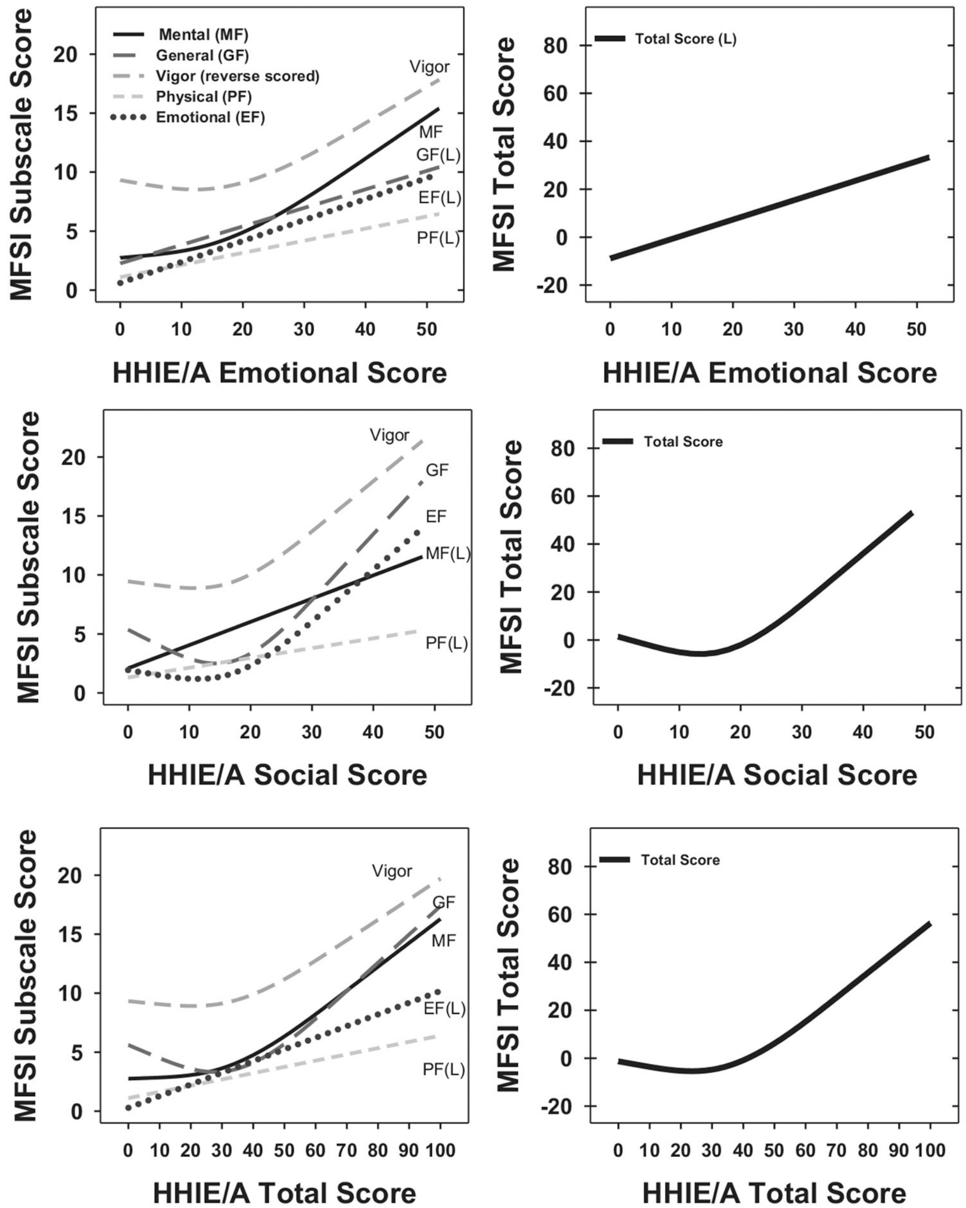

Fig. 3.

Quantile regression predictions of MFSI-SF subscale (*left column*) and total (*right column*) scores as a function of HHIE/A emotional (*top panel*), social (*middle panel*), and total (*bottom panel*) scores. Regression predictions assume a 67-year-old male with a 35 dB better ear PTA—this is the median age and hearing loss of the study respondents. EF indicates emotional fatigue; GF, general fatigue; HHIE/A, hearing handicap inventory for the elderly/adults; (L), linear function; MF, mental fatigue; MFSI-SF, multidimensional fatigue symptom inventory-short form; PF, physical fatigue; PTA, pure-tone average (see also Table 2).

TABLE 1.

Associations between better ear pure-tone average threshold (in dB HL) and median MFSI-SF ratings, by domain (N = 143[*])

MFSI Domain	Change in MFSI Domain Rating (95% CI)[†]	*p*
General fatigue (range: 0–24)	0.03 (−0.08 to 0.14)	0.64
Physical fatigue (range: 0–24)	0.04 (−0.00 to 0.08)	0.08
Emotional fatigue (range: 0–24)	0.02 (−0.04 to 0.09)	0.46
Mental fatigue (range: 0–24)	−0.01 (−0.07 to 0.05)	0.66
Vigor deficit (range: 0–24)[‡]	0.02 (−0.05 to 0.10)	0.61
Total fatigue (range: −24 to 96)[§]	0.08 (−0.21 to 0.36)	0.61

[*] Excludes 8 participants with incomplete MFSI-SF responses on at least one domain (see Materials and Methods) and 2 participants with missing better ear pure-tone average thresholds.

[†] Changes in MFSI domain ratings are for each one-point increase in better ear pure-tone average thresholds adjusting for age and gender.

[‡] Original MFSI vigor scores were reverse coded so that higher scores reflect higher levels of vigor deficit to be consistent with the negative outcomes of fatigue.

[§] The total fatigue score is the sum of the four fatigue domains minus the vigor domain (before reverse coding to indicate vigor deficit). Because the range of total fatigue score can vary over a larger range than individual domain scores, the larger changes in this measure associated with better ear pure-tone average thresholds are not directly comparable with the observed changes in domain-specific ratings.

CI indicates confidence interval; MFSI, multidimensional fatigue symptom inventory-short form.

TABLE 2.

Associations between self-reported HHIE/A scores and median MFSI-SF ratings, by domain (N = 142 *)

MFSI Domain	Change in MFSI Domain Rating (95% CI)†	*p*
Emotional HHIE/A scale (range: 0–52)		
General fatigue (range: 0–24)	0.16 (0.04–0.27)‡	0.007
Physical fatigue (range: 0–24)	0.10 (0.02–0.19)‡	0.018
Emotional fatigue (range: 0–24)	0.18 (0.10–0.26)‡	<0.001
Mental fatigue (range: 0–24)	0.32 (0.21–0.43)§	<0.001
Vigor deficit (range: 0–24)¶	0.25 (0.17–0.34)§	<0.001
Total fatigue (range: −24 to 96) ∥	0.81 (0.48–1.14)‡	0.003
Social HHIE/A scale (range: 0–48)		
General fatigue (range: 0–24)	0.50 (0.32–0.68)§	<0.001
Physical fatigue (range: 0–24)	0.08 (0.01–0.15)‡	0.018
Emotional fatigue (range: 0–24)	0.42 (0.22–0.61)§	<0.001
Mental fatigue (range: 0–24)	0.20 (0.11–0.28)‡	<0.001
Vigor deficit (range: 0–24)¶	0.40 (0.19–0.60)§	<0.001
Total fatigue (range: −24 to 96) ∥	1.90 (1.07–2.74)§	<0.001
Total HHIE/A scale (range: 0–100)		
General fatigue (range: 0–24)	0.24 (0.15–0.33)§	<0.001
Physical fatigue (range: 0–24)	0.05 (0.02–0.09)‡	0.002
Emotional fatigue (range: 0–24)	0.10 (0.05–0.15)‡	<0.001
Mental fatigue (range: 0–24)	0.19 (0.12–0.25)§	<0.001
Vigor deficit (range: 0–24)¶	0.16 (0.07–0.24)§	<0.001
Total fatigue (range: −24 to 96) ∥	0.91 (0.61–1.22)§	<0.001

*Excludes 8 participants with incomplete MFSI-SF responses on at least one domain (see Materials and Methods), 2 participants with missing better ear pure-tone average thresholds, and 1 participant with missing hearing handicap responses.

†Changes in MFSI domain ratings are for each one-point increase in HHIE/A score adjusting for age, gender, and better ear pure-tone average thresholds.

‡Associations between HHIE/A and MFSI domains are linear and constant across the full range of HHIE/A scores.

§Associations between HHIE/A and MFSI domains are nonlinear: changes in MFSI domain ratings are for each one-point increase in HHIE/A score for scores at or above the 75th percentile (scores ≥28, ≥26, and ≥54 for emotional, social, and total HHIE/A, respectively; see text and figures for results below the 75th percentile).

¶Original MFSI vigor scores were reverse coded so that higher scores reflect higher levels of vigor deficit to be consistent with the negative outcomes of fatigue.

∥The total fatigue score is the same as defined in Table 1. As in Table 1, the larger changes in total fatigue scores associated with HHIE/A scores are not directly comparable with the observed changes in domain-specific ratings due to differences in scale size.

CI indicates confidence interval; MFSI, multidimensional fatigue symptom inventory-short form; HHIE/A, hearing handicap inventory for the elderly (or adults; see Materials and Methods).