The Sound-Sensitive Tinnitus Index: Psychometric Properties of a Scale to Assess the Impact of Tinnitus Exacerbated by Sound

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Abstract

Context: Although studies of tinnitus exacerbated by sound exposure have indicated increased treatment challenges and intensified mental health and quality of life concerns, there is a lack of valid screening measures to differentiate or assess diagnostic factors and areas of impact unique to this specific symptom manifestation. Aims: The purpose of this study was to design a self-rated measurement tool that can accurately assess the subjective impact of tinnitus negatively modulated by external sound. Settings and Design: Based on review of established models of tinnitus and hyperacusis measurement and a two-part pilot study, the 20-item Sound-Sensitive Tinnitus Index (SSTI) was developed and administered in online survey format to 277 individuals worldwide. Methods and Material: Cronbach’s alpha was used to estimate reliability properties, and dimensional factor analysis was performed. To establish validity, statistical correlations of the SSTI were estimated with valid measures of related constructs including tinnitus, hyperacusis, depression, anxiety, and quality of life. Results: Statistical analysis yielded high levels of internal consistency reliability, and convergent validity was demonstrated through significant correlations with all established measures of related constructs. Initial factor analysis indicated two components split between overall functional impact and coping factors, while rotated factor analyses revealed four distinct scale dimensions, labeled: functional challenges, relational and communication challenges, coping factors, and prevention and hearing protection. Conclusions: As a valid and reliable measure, the SSTI fills an important gap as a clinical and research tool that can differentiate and assess severity and treatment progress in manifestations of combined tinnitus and auditory sensitivity symptoms.

Keywords: Assessment, hyperacusis, measurement, psychometrics, tinnitus

Key Messages: The Sound-Sensitive Tinnitus Index (SSTI) is a scale that was designed to assess the impact of auditory sensitivity on subjective tinnitus. The SSTI demonstrated high levels of reliability and validity, and thus should be considered in the assessment and treatment of tinnitus exacerbated by sound exposure.

INTRODUCTION

Tinnitus is generally defined as the perception of sound in the absence of external auditory stimuli.¹,² While several definitions of hyperacusis exist, it has been characterized as an experience of discomfort or pain after exposure to even moderate or quieter environmental sounds.³,⁴ Sound-sensitive tinnitus, by contrast, is defined in the present study as cases in which subjective tinnitus perception and/or distress are exacerbated by sound exposure, causing enduring discomfort, auditory sensitivity, and/or pain.⁵,⁶ This definition has precedent in prior observations that exposure to even moderate or lower levels of noise can exacerbate tinnitus in some cases,⁷-¹⁰ which has also been observed to result in heightened overall distress and negatively impacted treatment outcomes.¹¹-¹⁴

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Tinnitus has long been acknowledged to be a heterogeneous condition, meaning that instead of being a singular disorder, various differences exist in tinnitus perception, causal factors, comorbidities, distress levels, and appropriate treatment considerations.\[15,16\] Some of these differing clinical manifestations have been referred to as categories,\[17,13\] subgroups,\[14\] and subtypes,\[16,18\] reflecting the wide variance in symptom profiles that tinnitus and hyperacusis patients commonly report.\[19\] Sound sensitivity disorders have also been indicated as manifesting in several distinct types and have been categorized as pain, loudness, annoyance, and fear hyperacusis.\[20,21\] Yet overwhelmingly, research studies, treatment options, and clinical assessment measures have reflected a homogeneous approach.\[22,23\]

Due to the diverse etiologies and perceptual characteristics observed among tinnitus patients, researchers have suggested it incorrect to assume that a single standard treatment protocol is appropriate for all tinnitus patients.\[14,17\] This follows how some tinnitus cases produce much greater emotional distress and impact quality of life more severely than others, particularly when diagnostic and treatment indications are unclear.\[24,25\] Particularly for severe and disabling tinnitus, developing and standardizing relevant criteria for identifying subtypes with respect to appropriate treatment considerations has been proposed as a crucially important challenge.\[8,17,18,23,25,26,27\] As such, some researchers have suggested that being able to recognize, diagnose, and offer more effective treatments to heterogeneous presentations of tinnitus and hyperacusis are pressing clinical needs.\[8,14,28\]

Tinnitus affects approximately 10–15% of the global population,\[29\] significantly impacts mental health and quality of life for a subset of those who experience tinnitus,\[30,31\] and is currently the most predominant disability for U.S. veterans.\[32,33\] As hyperacusis is not consistently defined in the literature, prevalence rates have been reported at between 2% and 15% in the general population.\[34\] Defined broadly as loudness intolerance, hyperacusis has been shown to occur in roughly 10% of the general population,\[35,36\] although estimates of severely impactful hyperacusis have been suggested as extremely rare.\[10\] In addition to the proposed categories of loudness, pain, fear, and annoyance hyperacusis,\[20,21\] distinct manifestations of loudness intolerance also include misophonia, literally meaning hatred of specific sounds.\[37\] It has also been estimated that over 80% of individuals who report hyperacusis also experience tinnitus, while 40% of individuals with tinnitus also report hyperacusis.\[38\]

Other demographics associated with increased rates of tinnitus and sound sensitivity disorders include adults over 50 years of age and the elderly.\[39-41\] Due to the increasing use of personal music players and exposure to amplified sound at early ages, youth and adolescent populations are also suggested to have a high risk of developing hearing loss, tinnitus, and hyperacusis.\[42-44\] While prevention efforts and current hearing aid technology have been suggested as contributing to an overall decline in hearing loss rates in recent years,\[45\] it has also been indicated that decreasing levels of noise in an increasingly urban and technological world suggest that auditory issues including tinnitus and hyperacusis will continue to be major public health burdens.\[46-49\]

Due to the subjective nature of tinnitus and disorders of sound sensitivity, it has long been a challenge in clinical treatment to accurately measure these auditory phenomena.\[50,51\] Consequently, various self-report scales for tinnitus have been developed since the late 1980s. While some hyperacusis questionnaires have been analyzed for psychometric validity, they are far fewer in number compared with tinnitus. A recently published scale, the Index of Hyperacusis Symptoms (IHS), demonstrated strong psychometric properties including excellent internal consistency reliability of .94,\[52\] yet only questionable or unclear internal consistency reliability has been demonstrated among several hyperacusis measurements currently used in research and clinical practice.\[53,54\]

While in recent years, there have been efforts to measure sound sensitivity in relation to tinnitus,\[55,56\] existing measurements assess auditory sensitivity as a separate construct from tinnitus.\[52,53\] While a specific category entailing prolonged exacerbation of tinnitus by sounds below a threshold of causing lasting damage has been proposed as part of an intake protocol for Tinnitus Retraining Therapy (TRT), labeled “Category 4,”\[17,54\] no psychometrically validated questionnaire to date has been developed to specifically measure how tinnitus may be impacted by and potentially exacerbated from increased sound sensitivity.\[11\] Therefore, the aim of this study was to develop a psychometrically valid measure that can accurately assess the impact of auditory sensitivity on subjective tinnitus.

While aspects of comorbid tinnitus and hyperacusis have been proposed,\[8,11,18,25,33,37,38,55,56,54\] the characteristics and prevalence of tinnitus that is exacerbated by exposure to sound remains unclear. This is important, as it has been suggested that comorbid tinnitus and hyperacusis result in more severe psychological distress and social challenges than either condition alone.\[8,11,17,54\] The interplay of tinnitus perception and hyperacusis has also been linked to cochlear nerve degeneration after noise-induced hearing loss.\[11,57\] and has been suggested to further exacerbate tinnitus-related emotional distress through increased functional resting-state connectivity between the limbic system and the auditory cortex.\[28,38,59\]
when tinnitus and hyperacusis co-occur.\[^{8,16}\] As such, the purpose of this study was to design and psychometrically validate an original scale for assessing the impact of sound sensitivity on subjective tinnitus. The capacity to identify and assess the sound-sensitive tinnitus subtype will help clinicians and researchers to understand the particular clinical needs, prevalence, and risk factors of a population that is currently not well-represented in the clinical research literature.

**SUBJECTS AND METHODS**

In accordance with established methodologies of questionnaire construction,\[^{63,64}\] this psychometric study involved creating survey items based on specific areas of impact and impairment in comorbid tinnitus and hyperacusis as identified within the literature. Accordingly, an initial potential item pool was created based on a two-level process that included: 1) a thorough review of current established models of tinnitus and hyperacusis measurement including the Tinnitus Retraining Therapy (TRT) interview protocols, particularly with respect to Category 4,\[^{17}\] the Tinnitus Functional Index (TFI),\[^{65}\] and the hypersensitivity to sound questionnaire (GÜF)\[^{66,67}\], 2) pilot study results including thematic analysis of coded interviews with audiologists in the San Francisco Bay Area who treat tinnitus and hyperacusis, as well as qualitative feedback from members of an ATA-affiliated tinnitus support group in Los Altos, California. Pilot study data suggested that a minority of tinnitus support group participants reported sound-exacerbated tinnitus, and initial results were presented at the American Psychological Association national conference in Washington, DC, in August 2014.

Once all interviews and feedback were coded and analyzed for thematic content with regards to the intersection of sound-sensitivity and tinnitus, 46 proposed items were selected to address the most prominent areas of auditory sensitivity impact on tinnitus as represented in the current literature. After a systematic review, the initial item pool was divided into a 26-item set of questions concerning challenges with sound sensitivity and tinnitus, 20 remaining items that were reviewed for inclusion became the Sound-Sensitive Tinnitus Index (SSTI) that was used in the present study.

Items such as “After hearing loud sounds, my tinnitus symptoms can become worse” were followed by a 5-point Likert-type scale that represented varying levels of severity, including “not at all,” “a little bit,” “somewhat,” “quite a bit,” and “very much so.” Based on feedback from pilot study participants, the term “loud” was included in several items so as to portray the phenomena of sound that may feel subjectively excessive, loud, or painful in so far as to cause lasting exacerbation of auditory tinnitus perception and/or comorbid tinnitus-related distress, even though it may not appear to be loud or problematic for the average individual or clinicians measuring sound levels audiometrically.

All 20 items were followed by the same 5-point Likert-type scale. However, while the first 16 items were scored on a basis of a higher number response equaling a higher level of negative symptom or impact, the remaining four items related to respondents’ capacity to effectively cope with their symptoms and thus were scored on a basis of a higher rated response equaling a more positive capacity to cope. Thus, these last four items are scored inversely, or negatively, and were included to provide clinicians a means to assess and initiate conversations about coping, which has been shown to mitigate both tinnitus distress\[^{68}\] and hyperacusis severity.\[^{69}\]

**OTHER MEASURES USED IN THE PRESENT STUDY**

Statistical relationships between constructs related to sound-sensitive tinnitus and the SSTI were examined to assess convergent validity. Because of the high comorbidity of mental health symptoms reported among tinnitus and hyperacusis populations,\[^{54,24,70,71}\] brief measures pertaining to depression, anxiety, and quality of life were also used to measure convergent validity and elucidate areas of psychosocial impact. Criteria for measurement inclusion included strong psychometric properties and relevance to established factors of enduring tinnitus and sound sensitivity disorders.

Accordingly, participants were asked to complete questions about demographics and were administered the TFI, the World Health Organization Abbreviated Quality of Life Scale (WHOQOL-BREF),\[^{72}\] the Patient Health Questionnaire screener for depression and anxiety (PHQ-4),\[^{73,74}\] the Inventory of Hyperacusis Symptoms (IHS),\[^{52}\] and the SSTI. The psychometric properties of the established scales that were used to measure convergent validity are detailed in the following paragraphs.

**TFI**

The TFI is a 25-item questionnaire that was designed to measure the severity of chronic subjective tinnitus.\[^{65}\] The TFI has demonstrated excellent internal consistency reliability (Cronbach’s alpha = 0.97) and has shown sound convergent validity both internally and regarding scaled ratings of tinnitus severity.\[^{65}\] Factor analysis yielded eight dimensions, including cognitive, auditory, intrusive, sleep, relaxation, quality of life, emotional, and sense of control.\[^{65}\] Permission to use the TFI in this study was obtained through Oregon Health and Science University.

**PHQ-4**

The PHQ-4 is a four-item questionnaire that measures the likelihood of mental health conditions relating to depression and anxiety.\[^{74}\] Divided into two parts consisting of...
depression and anxiety symptoms that contain two questions each, items related specifically to depressive symptoms have shown up to 90% specificity in identifying the presence of MDD, and questions relating to anxiety symptoms have shown 82% specificity in identifying potential presence of GAD, social anxiety disorder, and PTSD. Internal consistency reliability analysis of the PHQ-4 resulted in a Cronbach’s alpha value of 0.82, and sound convergent validity was demonstrated with measures of self-esteem, life satisfaction, and resilience. Permission to use the PHQ-4 in this study was obtained through the Pfizer Corporation, New York, NY.

WHOQOL-BREF

The WHOQOL-BREF is a 26-item scale developed to measure quality of life in domains including physical, psychological, social relationship, and environmental health in an abbreviated structure from the original 100-item scale. Overall, the WHOQOL-BREF has demonstrated good internal consistency reliability (Cronbach’s alpha = 0.78) as well as sound discriminant validity as measured with data obtained from a sample population from 24 countries on five continents. Permission to use the WHOQOL-BREF was granted by the World Health Organization, Geneva, Switzerland.

INDEX OF HYPERACUSIS SYMPTOMS (IHS)

The IHS is a set of questions created to address a gap in available hyperacusis measurement tools that yielded excellent initial internal consistency reliability of 0.94. This scale was then further developed and analyzed with data from 469 participant questionnaire administrations and displayed sound convergent and content validity through correlations with global ratings of sound intolerance, as well as established scales of tinnitus, mental health, and quality of life.

PARTICIPANT RECRUITMENT

Because of the pervasiveness of tinnitus and sound sensitivity issues across cultures and ethnicities, it was deemed essential to obtain a sample large enough to represent a broad scope of individuals worldwide who are afflicted by these conditions. As such, information about participating in this study was originally posted in various international online support groups including the website tinnitustalk.com. Social media advertisements included brief posts that simply requested participation in a study investigating the impact of sound sensitivity in tinnitus. Participants were also sought through collaboration with several audiologists in the San Francisco Bay Area and with support groups affiliated with the American Tinnitus Association (ATA), which sponsored this study through a small research grant award. Notification about recruitment was also posted on the ATA’s website and on the websites of international tinnitus organizations in primarily English-speaking countries including the United Kingdom, Canada, and Australia.

Upon arriving at the study website, participants were asked if they consent to participate in the study and were informed of the minimal risk of potential emotional discomfort due to the mood and anxiety symptoms known to be comorbid with tinnitus and hyperacusis. Upon agreeing, participants were then linked to a set of questions related to study inclusion delimitations of having tinnitus, and that their tinnitus was at least occasionally exacerbated by sound exposure. If participants answered yes to both of these delimitations, they were then guided to the complete set of demographic questions and measures used in this study. To protect participant confidentiality, no collected data contained any information that could potentially identify any participants.

SAMPLE

Participants who provided at minimum demographic information and met all inclusion criteria totaled 335 individuals from 32 countries, primarily the United States and Europe. An additional 85 individuals accessed the study website, but two did not consent to the terms of participation, six did not meet the criteria of having tinnitus, and 65 individuals were excluded due to not experiencing tinnitus exacerbation after hearing loud sounds. Another 58 individuals consented to study terms, met inclusion criteria, and provided basic demographic information, but did not complete all included questionnaires. The total number of completed SSTI administrations that included all demographic data and other questionnaires was 277.

PARTICIPANT DEMOGRAPHICS

Study participants were primarily female, White, living in the United States, and above the age of 40. See Table 1 for more detail on participant demographics. Among those who consented to participate and reported experiencing tinnitus (N = 400), 83.8% (N = 335) reported at least occasional sound exacerbation after sound exposure. As shown in Table 2, 29.2% (N = 81) reported no hearing loss, 41.5% (N = 115) reported mild hearing loss, 20.9% (N = 58) reported moderate hearing loss, 7.9% (N = 22) reported severe hearing loss, and 0.4% (N = 1) reported Deafness.

RESULTS

Statistical analysis was performed using SPSS Version 23 with data from self-report results representing 277 participants who completed the 20-item alpha version of the SSTI questionnaire. Cronbach’s alpha was calculated to estimate the SSTI’s internal consistency reliability, which yielded a score of 0.89. This indicates a very high correlation between all scale items as they relate both individually and as a whole. A full list of item means and standard deviations of the SSTI is displayed in Table 3.
Additional evaluation of validity included two-tailed convergent correlational analysis with established scales of constructs known to relate to sound-sensitive tinnitus. Significant correlations were found between the SSTI and the Tinnitus Functional Index (TFI; $r = 0.55$, $P < 0.001$), the World Health Organization Abbreviated Quality of Life Scale (WHOQOL-BREF; $r = -0.57$, $P < 0.001$), the Patient Health Questionnaire depression screener (PHQ-2; $r = 0.54$, $P < 0.001$), and the General Anxiety Disorder screener (GAD-2; $r = 0.45$, $P < 0.001$). The highest correlation was found with the Inventory of Hyperacusis Symptoms (IHS; $r = 0.80$, $P < 0.001$). These results indicate sound validity through statistical correlations between the SSTI and psychometrically established scales that measure constructs related to sound-sensitive tinnitus, including hyperacusis, tinnitus, quality of life, anxiety, and depression.

**FACTOR STRUCTURE OF THE SSTI**

In determining the SSTI’s dimensional factor structure, a principal component analysis was performed. Items with initial eigenvalues greater than or equal to 1 were sorted into discrete factors, with 0.3 set as cutoff in order to reduce excessive weak factor loadings. Items were then orthogonally rotated using the Varimax method with Kaiser normalization to maximize loading dispersion within factors and to increase interpretability among factor clusters.\[76,77\]

While initial principal component analysis yielded two factors of statistical significance and two others that did not show statistical significance, rotated component analyses yielded four total factors inherent in the SSTI. These factors were labeled (a) functional challenges, (b) relational and communication challenges, (c) coping factors, and (d) prevention and hearing protection. Cumulatively, these factors represent 63% of the total variance of responses, with Factor 1 accounting for 40% of total variance, Factor 2 accounting for 9.5% of the total variance, Factor 3 accounting for 7.5% of the total variance, and Factor 4 accounting for 6% of the total variance. While most items loaded onto one single factor, some items yielded

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### Table 1: Participant demographics ($N = 277$)

| Characteristic              | $n$ | %  |
|-----------------------------|-----|----|
| Age range (in years)        |     |    |
| 18–21                       | 6   | 2.2|
| 22–29                       | 23  | 8.3|
| 30–39                       | 57  | 20.5|
| 40–49                       | 59  | 21.2|
| 50–59                       | 74  | 26.6|
| 60–64                       | 38  | 13.7|
| 65+                         | 20  | 7.2|
| Gender                      |     |    |
| Male                        | 121 | 44.0|
| Female                      | 155 | 56.0|
| No response                 | 1   | 0.4|
| Armed Services veteran      |     |    |
| Yes                         | 11  | 4.0|
| No                          | 266 | 96.0|
| Ethnicity                   |     |    |
| White/European              | 255 | 92.0|
| Hispanic/Latino             | 11  | 4.0|
| Black/African American      | 1   | 0.4|
| Asian/Pacific Islander      | 8   | 3.0|
| Native American/Indigenous  | 3   | 1.1|
| Location                    |     |    |
| United States               | 118 | 42.4|
| United Kingdom              | 55  | 20.0|
| Australia                   | 25  | 9.0|
| Canada                      | 20  | 7.2|
| Ireland                     | 5   | 1.8|
| New Zealand                 | 1   | 0.4|
| Continental Europe          | 40  | 14.4|
| Africa                      | 3   | 1.1|
| South America               | 6   | 2.2|
| Asia                        | 4   | 1.4|

*Note.* Total of percentages are not 100 for every characteristic because of rounding.

### Table 2: Level of hearing loss reported by study participants ($N = 277$)

| Hearing loss | #   | %  |
|--------------|-----|----|
| None         | 81  | 29.2|
| Mild         | 115 | 41.5|
| Moderate     | 58  | 20.9|
| Severe       | 22  | 7.9|
| Deafness     | 1   | 0.4|

### Table 3: Item means and standard deviations ($N = 277$)

| Item | Mean | SD  |
|------|------|-----|
| 1    | 3.8  | 0.98|
| 2    | 3.4  | 1.24|
| 3    | 3.9  | 1.08|
| 4    | 3.6  | 1.23|
| 5    | 3.6  | 1.16|
| 6    | 3.7  | 1.15|
| 7    | 3.3  | 1.38|
| 8    | 3.8  | 1.16|
| 9    | 3.7  | 1.30|
| 10   | 3.5  | 1.25|
| 11   | 3.0  | 1.39|
| 13   | 2.9  | 1.42|
| 13   | 2.9  | 1.42|
| 15   | 3.3  | 1.38|
| 16   | 3.3  | 1.46|
| 17   | 2.7  | 1.27|
| 18   | 2.4  | 1.02|
| 19   | 2.2  | 1.04|
| 20   | 3.1  | 1.23|
correlations with dual factors. Wherever this occurred, lower statistical factor loadings were discarded in favor of the highest possible correlation. A full list of factors and item inclusion is shown in Table 4.

### SPECIFIC COMPONENTS

To address the initial component factor analysis separation of items between the 16 items specific to sound sensitivity impact and the four items describing coping factors, reliability analysis was also performed in each of these two larger subcategories of the scale. Accordingly, the 16 sound sensitivity items yielded a Cronbach’s alpha of 0.93, indicating excellent internal consistency reliability for all items relating specifically to the impact of sound sensitivity on subjective tinnitus. The coping items were also independently analyzed and demonstrated a Cronbach’s alpha of 0.55, reflecting questionable internal consistency reliability among the set of four questions specifically addressing coping factors.

### SCORING THRESHOLD ESTIMATES

Overall mean scores and standard deviations of the 277 completed SSTI administrations provided an estimate of preliminary scoring thresholds. The 20-item scale yielded a mean score of 65.2, with 14.1 and total variance of 199.7. However, considering that the last four questions were negatively scored, estimates were also set separately for the first 16 questions and the last four questions. The mean for the first 16 questions was 54.9, with a standard deviation of 14.2 and total variance of 201.2, and the mean of the negatively scored last four questions was 10.3, with a standard deviation of 3.0 and total variance of 9.0.

### DISCUSSION

Tinnitus exacerbated by sound exposure is a potentially debilitating condition and has been identified as one of the most challenging manifestations of tinnitus to effectively treat. Accordingly, we set out to create and

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| Table 4: Sound-Sensitive Tinnitus Index (SSTI) factor structure, varimax rotation with Kaiser normalization (N = 277) |
|---|---|---|
| Factor | Item # | Item content | Factor loading |
| Functional challenges | 1 | After hearing loud sounds, my tinnitus symptoms can become worse. | 0.79 |
| | 2 | My tinnitus symptoms can get worse for even several days after I am exposed to loud sounds. | 0.76 |
| | 3 | It is difficult for me to be in noisy situations because it makes my tinnitus worse. | 0.80 |
| | 4 | In loud situations, I feel like I need to ask people to lower the volume for fear of my tinnitus getting worse. | 0.64 |
| | 5 | I feel like my burden of tinnitus is increased because it gets worse after hearing loud sounds. | 0.78 |
| | 6 | Being sensitive to sounds makes it harder to cope with having tinnitus. | 0.67 |
| Relational and communication challenges | 7 | I find my challenges with sound sensitivity and tinnitus difficult to explain to doctors, ear-nose-throat (ENT) physicians, and/or audiologists. | 0.46 |
| | 8 | My tinnitus and sound sensitivity can become worse when I am under stress. | 0.38 |
| | 9 | Because of my tinnitus and sensitivity to sounds, I sometimes avoid social situations that I fear could make my tinnitus worse. | 0.78 |
| | 10 | The impact of hearing loud sounds on my tinnitus can be challenging to explain to my friends and family. | 0.55 |
| | 11 | My tinnitus and sound sensitivity symptoms have negatively impacted my relationships with friends and family. | 0.86 |
| | 12 | I have a hard time being in groups of people because it makes my tinnitus worse. | 0.80 |
| | 13 | Even being around 3 people in which multiple conversations are happening at once can make my tinnitus worse. | 0.71 |
| | 14 | Performing necessary tasks that can be noisy such as housework, errands, and shopping can make my tinnitus worse. | 0.70 |
| | 15 | I feel like my tinnitus and sound sensitivity have gotten worse over time. | 0.48 |
| | 16 | My tinnitus and sensitivity to sounds have negatively impacted my ability to pursue my hopes and dreams. | 0.80 |
| Coping factors | 17 | When my tinnitus gets worse after hearing loud sounds or for other reasons, I can use ambient sounds or background noise to help my symptoms. | 0.66 |
| | 18 | I feel like I can manage my tinnitus and sound sensitivity symptoms, even when they get bad. | 0.81 |
| | 19 | I feel as though I have enough resources to help me deal with my tinnitus and sound sensitivity symptoms, even when they become overwhelming. | 0.81 |
| Prevention and hearing protection | 20 | If I am exposed to loud sounds, using hearing protection can help prevent my tinnitus from getting worse. | 0.80 |
establish a psychometrically valid instrument for measuring the impact sound can have on subjective tinnitus severity and distress. This involved constructing the 20-item SSTI with the objective of creating a comprehensive measure of relevant aspects to the experience of sound-sensitive tinnitus that prior research has shown as unique to this distinct clinical presentation.

After designing the scale and study protocol, data were collected and analyzed from a sample of 277 participants worldwide, primarily from North America, Western Europe, and Australia. Statistical analysis of the psychometric properties from all completed study protocols showed that the SSTI demonstrated high levels of internal consistency reliability, as well as sound convergent validity through significant correlation with established measures of quality of life, anxiety, and depression as well as tinnitus and hyperacusis severity. While initial factor analysis split the items into two general diagnostic and coping domains, rotated component analysis clarified statistical categories within the SSTI and revealed four scale dimensions that reached statistical relevance.

Considering that the inclusion criteria required participants to be at least mildly symptomatic with respect to having tinnitus that is exacerbated by sound, the mean score and standard deviations of this population sample were utilized to estimate scoring thresholds and severity levels for clinical practice. Accordingly, as applicable, clinical outcomes may be measured by determining the total score of the SSTI, with a score of 51 being the initial estimate for clinical and diagnostic import. Additional clarity may be gained by providing attention specifically to scores within the functional, relational, and communicative impact domains represented in the first 16 items, and the coping and prevention factors as represented in the inversely scored final four questions.

A strength of this study is that statistical analysis revealed robust reliability and validity of a new measure that clinicians and researchers can use in diagnosing and assessing challenges experienced by individuals with tinnitus exacerbated by exposure to sound. The SSTI also demonstrated reliability in abbreviated format of only the first 16 items as differentiated through initial component analysis. This variation of format can provide clinicians and researchers more flexibility in how they use this scale, specifically regarding how functional and protective factors are considered as they relate to considerations with treatment planning and in the development of clinical interventions. Taking all scale items and dimensions into account, the SSTI can help clinicians and researchers gain more comprehensive portraits of the impact endured by patients reporting tinnitus perception and distress that is exacerbated by sound.

Another contribution of this study is that it provided greater means by which to elucidate relevant components to the experience of sound-sensitive tinnitus, thus differentiating this subtype from other symptom manifestations, including complications having to do with tinnitus reactivity. In this regard, we suggest reactive tinnitus to be characterized by modulation from external sound with respect to loudness, pitch, tone, or quality, yet differentiated from sound-sensitive tinnitus in that it does not necessarily represent a persistent exacerbation of tinnitus perception, distress, or related pain once the external sound subsides.[5,6] Thus, sound-sensitive tinnitus is distinguished primarily by the enduring duration of negative impact and exacerbation of tinnitus perception and/or comorbid related distress as moderated by external sounds.

While the full 20-item SSTI yielded strong validity and reliability and therefore appears appropriate for use in clinical practice and research, limitations include that inconclusive results were found for the four-item coping index of the SSTI as a stand-alone measure. While the 16-item functional impact abbreviation yielded excellent internal consistency reliability, the four-item coping abbreviation demonstrated only questionable internal consistency reliability on its own. This may be due to variances in ways that people cope or differences in individual comfort level using ear plugs, especially considering that exposing patients to increasingly loud sound levels and decreasing hearing protection use are fundamental aspects in many behavioral interventions for hyperacusis.[78] Accordingly, it is not recommended that the four coping items be used independently of the scale in its entirety, but rather that they may contribute to providing context relative to the other items and dimensions in the scale.

Other limitations include lack of audiometric data concerning participant hearing function and overall auditory health. Considering that this study relied entirely on subjective report, variances in participant responses could not be measured against observed data from professional clinical settings. Consequently, future studies should include audiometric data in confirming the SSTI’s construct validity. While a sufficiently sized sample was achieved to account for potential errors or discrepancies in participants’ subjective reports, the length of the questionnaires combined with the international scope of this study may have also led to testing fatigue, particularly for participants for whom English is not a first language. Furthermore, considering the overwhelmingly White sample, this study did not represent a sufficiently diverse population for generalizing the experience of sound-sensitive tinnitus to varied cultural backgrounds. As such, it is important that future studies recruit a more diverse sample to better understand diversity factors that may apply to the assessment and treatment of sound-sensitive tinnitus.

Another potential limitation and possible avenue for further investigation pertains to a challenge we experienced in attempting to concretize subjective phenomena of tinnitus pain after sound exposure, particularly the use of the term “loud.” In the final stages of scale construction, we made the decision to include the term consistent with the feedback we were receiving from individuals who endure this condition,
Further avenues of research implied by this study’s findings include refining the SSTI guided by results of statistical analyses and other gathered data as it may improve scale items and definitions. Once refined, the SSTI should be tested in participant trials that include audiometric data collection, with the aim of confirming the psychometric properties yielded in this study and to measure correlations with more objective data such as hearing tests and otoacoustic emissions. Characteristics of patients who report sound-sensitive tinnitus can then also be compared with control groups as well as with individuals who have other tinnitus subtype and auditory sensitivity disorder manifestations.

For example, even though advertisements for participation specifically requested individuals whose tinnitus is exacerbated by sound, 16% of those who logged onto the study website did not meet this criterion. While Category 4 has been suggested to be the rarest\[13\] and be irrelevant to hearing loss,\[17\] our results indicated that 84% of all individuals with tinnitus who logged on to the study reported sound exacerbation symptoms and that 71% indicated at least mild hearing loss. Therefore, it would be beneficial to further clarify and differentiate these characteristics towards a more comprehensive portrait of Category 4 and sound-sensitive tinnitus.

Using the SSTI, future studies may also seek to establish more accurate estimates of prevalence in the general population as well as specifically among auditory disorder and tinnitus subtype populations. While 84% of individuals who reported tinnitus and consented to participate identified sound exacerbation of their tinnitus, confirmation of the presence of sound-sensitive tinnitus as well as the severity and impact of this subtype need to be further clarified. In addition, study results can assist in the development of diagnostic factors pertinent to the sound-sensitive tinnitus subtype and can help clarify specific mental health and quality of life issues this population faces. This may then assist researchers in redesigning treatment protocols to better suit the treatment concerns associated with this subtype, including reconsidering or adapting the use of hearing aids, and adjusting recommendations regarding the use of hearing protection, which may be specifically beneficial to individuals enduring sound-sensitive tinnitus in preventing setbacks and exacerbations in symptoms brought about by noise exposure. Clinical implications of this study include that practitioners can use study findings to identify the presence and severity factors of sound-sensitive tinnitus in clinical practice. By using the SSTI when patients report tinnitus that is worsened by auditory sensitivity, clinicians can initiate conversations and further testing to gain a more accurate understanding in their assessments of symptom severity and overall impact on mental health and quality of life. This will assist treatment planning, provide better outcome predictions, and help to overcome many of the challenges in being understood by healthcare practitioners that individuals with sound-sensitive tinnitus have reported.\[6\]

Due to the complexity of factors involved at the intersection of tinnitus and auditory sensitivity in consideration of our intention to create a brief, valid, and easy-to-administer measure, the SSTI alone cannot entirely assess or elucidate the nature of tinnitus or auditory sensitivity exacerbation. However, it is hoped that the SSTI can differentiate the presence and severity of sound-sensitive tinnitus, and thus generate conversations between patients and providers towards more individualized care and treatment planning. Accordingly, results from this undertaking can offer indications for multidisciplinary treatment and psychological care for patients who are impacted by sound sensitivity that further intensifies their tinnitus symptoms. For example, clinicians and audiologists who observe both tinnitus and hyperacusis in their patients may use the SSTI in order to better identify treatment goals and enhance understanding, rapport, and trust between patient and practitioner. Since some current tinnitus and hyperacusis treatments emphasize increased environmental noise exposure,\[79\] the SSTI may help determine if treatments that endorse increased noise exposure are appropriate, and help to further tailor existing treatments to individual patient needs. Thus, a scale that can accurately measure the impact of sound-sensitivity in subjective tinnitus may be of benefit to patients who may meet criteria for this subtype, yet currently lack diagnostic clarity. Additionally, the SSTI may be used by researchers as an evaluation tool, and even a potential screening for participants to investigate the neurological correlates of sound-sensitive tinnitus as distinct from other subtypes. Future research of this nature may potentially illuminate critical biological and clinical aspects of this challenging condition that currently has no cure.

Through the creation of a psychometrically sound self-report measure, clinicians and researchers now have a tool that can contribute to a more lucid diagnostic portrait concerning areas of impact in the lives of those who are afflicted with sound-sensitive tinnitus, an incurable, complex, and oftentimes devastating condition. Increased comprehension of the unique variables inherent in the sound-sensitive tinnitus subtype will make it possible to accurately identify essential components to patients’ unique challenges, thus decreasing stigma and enhancing understanding where it may be lacking. Along these lines, the SSTI can provide researchers, practitioners, and patients the opportunity to address crucially important areas of impact in social, occupational, and psychological functioning. We hope that such efforts may lead to more effective care where it is most pressingly needed.
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