Music Perception and Music-Related Quality of Life in Adult Cochlear Implant Users: Exploring the Need for Music Rehabilitation

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Objectives: Cochlear implant (CI) users face difficulties in accurately perceiving basic musical elements such as pitch, melody, and timbre. Music significantly affects the quality of life (QoL) of CI users. Individually and culturally influenced music perception exceeds psychophysical measures in capturing the subjective music enjoyment of CI users. Understanding the music perception, enjoyment, and habits of CI users is crucial for approaches to improve music-related QoL (MuRQoL). Therefore, this study aims to investigate music perception skills, experiences, and participation in music activities in a large group of adult CI users, and to understand the importance of these factors and their impact on QoL of CI users.

Design: This study included 214 CI recipients with diverse auditory experiences who were aged between 18 and 65 years and were unilateral, bimodal, or bilateral users for at least 1 year and 193 normal hearing (NH) controls. All participants completed the information forms and the MuRQoL questionnaire. To assess the impact of music on QoL and identify personalized rehabilitation needs, the scores for each question in both parts of the questionnaire were intersected on a matrix. Data were presented in detail for the CI group and compared between CI and NH groups.

Results: A statistically significant difference was found between the matched CI and NH groups in favor of the NH group in terms of music perception and music engagement. Participants who received music education at any point in their lives had significantly higher MuRQoL questionnaire scores. There was no significant relationship found between the duration of auditory rehabilitation, pre-CI hearing aid usage, music listening modality, and MuRQoL questionnaire scores. Unilateral CI users had significantly lower scores in music perception and music engagement subsections compared with bimodal and bilateral CI users. Also, it was found that music had a strong negative impact on QoL in 67/214 of the CI users.

Conclusions: Although CI users scored significantly lower than NH individuals on the first part of the questionnaire, which asked about musical skills, enjoyment, and participation in musical activities, findings suggest that CI users value music and music enjoyment just as much. The study reveals the influence of factors such as education level, age, music education, type of hearing loss and auditory rehabilitation on music perception, music enjoyment, and participation in music activities through self-report. The results indicate that for many CI users, music has a strong negative impact on QoL, highlighting the need for personalized music interventions, the inclusion of self-report questionnaires, and music perception tests in clinical evaluations.

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Key words: Cochlear implants, Music perception, Music rehabilitation, music-related quality of life.

Abbreviations: CI = cochlear implant; FS = Frequency Scale; HA = hearing aid; HL = hearing loss; IS = Importance Scale; M = mean; ME = music engagement; MP = music perception; MuRQoL = music-related quality of life; N/A = not applicable; NH = normal hearing; QoL = Quality of Life; SNI = strong negative impact; SPI = strong positive impact; WNI = weak negative impact; WPI = weak positive impact.

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INTRODUCTION

Music consists of pitch (which forms melody and harmony), timbre, rhythm, and amplitude, all of which contribute to the perception of music, including its expressiveness and meaning (McDermott 2004; Bhatara et al. 2011). Unfortunately, cochlear implants (CIs) do not provide an adequate representation of pitch, time, and amplitude. Even though language and music have some characteristics in common, such as pitch, tempo, rhythm, and duration, music needs more complex resolution processes (Shannon 2005; Galvin et al. 2009). Some of the limitations CI users experience while perceiving fundamental musical elements accurately include pitch perception, melody recognition, timbre identification, melodic contour analysis, and dissonance-harmony perception.

There are many reasons for poor music perception; the physical/technological limitations of CIs, inadequate transfer of spectro-temporal fine structure information, biological limitations of the hearing system due to auditory deprivation, poor spectral resolution caused by interactions between stimulation sites in the cochlea, and acoustic limitations due to complex acoustic cues needed for music perception are few of them (Limb & Roy 2014; Fuller et al. 2021). Consequently, sounds transmitted via CIs primarily capture slowly varying spectro-temporal information while lacking fine structure details, and the transmission of amplitude information is affected due to the compressed dynamic range (Won et al. 2010; Gauer et al. 2019). These aspects collectively contribute to CI users' ability to enjoy music, and as a result, their capacity to derive full satisfaction from musical experiences remains constrained (Moon & Hong 2014).

Music is not just a form of entertainment; it serves as a means of emotional expression, cultural identification, and personal connection. Therefore, the inability to fully appreciate music due to restricted music perception skills can also be emotionally distressing. It is crucial to address these limitations and develop strategies to improve music perception in individuals with CIs to improve their overall quality of life (QoL) (Gfeller et al. 2019; Yuksel et al. 2023).

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There is considerable variation in music perception abilities among CI users. For example, some CI users can detect pitch differences of one semitone, while others cannot do so for an octave (Galvin et al. 2009). Apart from the patient (e.g., cognitive skills, residual hearing, and demographics) and device characteristics related to variation in speech perception, music-related factors such as pre-implantation music experience, music preferences, musical education or training, various psychoacoustical abilities, or the relative significance of music to different people should be considered (Gfeller et al. 2008; Looi et al. 2012).

Incorporating music into one's everyday routine can provide enjoyment and enhance one's mental well-being. Therefore, it is stated that music has the ability to enhance the QoL, and music therapies can also exert positive effects in this regard (Zatorre & Salimpoor 2013). For many CI users with postlingual hearing loss, music becomes essential, particularly after basic speech perception. A significant number of adult CI users with postlingual hearing loss, who have previously had exposure to music, express a desire to regain the ability to enjoy, understand, and listen to the music they formerly cherished (Leal et al. 2003; Lassaletta et al. 2008a). However, CI users frequently express that they dedicate less time to listening to music following cochlear implantation due to their dissatisfaction with the musical experience (Looi et al. 2012). In addition, it has been indicated that those who use their CIs to listen to music more frequently or engage in musical activities tend to have greater appreciation of music (Lassaletta et al. 2008b, 2009; Fuller et al. 2018). Given these findings, it is reasonable to think that there is a relationship between musical satisfaction and the amount of time spent listening to music (Looi & She 2010). However, it is unclear whether CI users who listen to more music do so because they receive a better signal in the first place, whether more listening leads to improvement, or if both occur in different phases or contexts. Therefore, it is important to acknowledge that the relationship between perception and enjoyment is complex, and its causality remains incompletely comprehended.

As with the music perception, there are significant differences in music listening habits and music enjoyment among CI users. Most studies report a correlation between music education and music enjoyment (Prevoteau et al. 2018). Nevertheless, there are cases where music experiences might have a negative effect on the enjoyment of music following implantation (Migirov et al. 2009). Individuals with postlingual hearing loss who were previously familiar with music are often disappointed with poor sound quality after implantation if they are not well guided or have unrealistic expectations (Looi & She 2010). These individuals who are unable to adapt to the auditory differences when listening to music with their CIs tend to reduce their music consumption or completely abstain from it following the implantation procedure Dritsakis et al. (2017a). However, CI users with prelingual hearing loss are less likely to have an opposition to listening to or not liking music (Migirov et al. 2009).

Music's Influence on the QoL of Adult CI Users

Music, as a universal art form, holds the remarkable ability to evoke powerful emotions, enrich and convey the most complex abstract concepts, and therefore can have significant impact on the QoL (Lassaletta et al. 2009). It is important to recognize that music perception is a deeply personal and culturally influenced phenomenon. Consequently, relying solely on psychophysical measures may not fully capture music listening habits and the subjective appreciation of CI users (Yuksel et al. 2020).

The factors that contribute to the enjoyment of music are still a topic of discussion, considering that the perception of music is very subjective and individualistic. Therefore, it is crucial to evaluate the importance of music in individuals' lives and its impact on their QoL. This assessment is not only necessary to measure the advantages obtained from music rehabilitation, but also to define rehabilitation needs and monitor individuals in the clinical setting.

Several studies have examined the correlation between music and QoL in adult CI users. These studies mostly examined the relationship between the music scores obtained and the ratings of QoL (Zhao et al. 2008; Lassaletta et al. 2009; Fuller et al. 2013). In two studies by Lassaletta et al. (2008b, 2009), it was revealed that those who gave high scores on statements about musical sound quality also had higher QoL scores. Studies showing a relationship between music listening and QoL in CI users with postlingual hearing loss support subjective comments regarding the significance of music and its positive effects on the emotional and social domains in life Dritsakis et al. (2017b); Gfeller et al. 2019). Contrary to these findings, no significant relationship was found between music enjoyment and QoL in adults with prelingual hearing loss who underwent implantation during adolescence. The lack of a relationship between music enjoyment and QoL in prelingually deafened—late implanted CI users is believed to be related to specific factors, including limited exposure to important sounds before hearing loss, a prolonged period of auditory deprivation before implantation, and inadequate development of auditory memory (Fuller et al. 2013).

Research on how CI users perceive music has drawn more attention in the last few years. However, the majority of research in this area has been on the music perception of CI users and the development of various methods to assess music perception. Given the importance and role that music plays in people's daily lives, it is important to study both perceptual accuracy and the extent to which people enjoy and engage with music (Fuller et al. 2021). For example, some CI users may enjoy the sound they hear, despite their limited musical abilities (Fuller et al. 2013). Gaining a more comprehensive understanding of the music perception, music enjoyment, and music listening habits of CI users can help clinicians and researchers in raising awareness of the music perception abilities and experiences of CI users. This understanding can also highlight the significance of these abilities and experiences and their influence on QoL.

We hypothesized that CI users would have poorer self-reported music perception skills compared with normal hearing (NH) individuals, resulting in decreased music-related QoL (MuRQoL). In addition, we hypothesized that subjective music perception scores are influenced by individual and audiological factors. The aim of this study was to explore the self-reported music perception skills, music-related experiences, and approaches to music activities in a large group of adult CI users. We aimed to understand the importance of these skills and experiences, and their impact on the MuRQoL of CI users. We also investigated whether there were differences in MuRQoL, music perception abilities, and music-related experiences.

These differences were analyzed based on individual factors including age, auditory rehabilitation, and music education, as well as audiological factors such as the type and duration of hearing loss, hearing modality, music listening modality, and duration of CI use. We believe that the information obtained has the potential to shed light on auditory rehabilitation practices and assist in the development of targeted rehabilitation strategies for the specific needs of CI users. This has the potential to improve their QoL by increasing their enjoyment of music.

MATERIALS AND METHODS

Participants

A total of 407 individuals participated in the study, including 109 female and 105 male CI users (M = 32.58 years, SD = ±13.02) and 114 female and 79 male NH adults (M = 30.35 years, SD = ±8.84) aged between 18 and 65 years. For all CI users, the conditions of having bilateral severe to profound sensorineural hearing loss, and being a stable unilateral, bimodal, or bilateral CI user for at least 1 year were considered. Hearing loss occurring before the age of 2 years was considered as prelingual hearing loss and hearing loss occurring at the age of 2 years and later was considered as postlingual hearing loss. Both CI users and NH participants with professional music education (those currently taking music lessons, studying any instrument or singing, musicians, and those whose university education is related to music), or additional mental and neurological disorders were excluded from the study. To better represent typical CI users, only participants who had received music education as part of compulsory schooling were included. In the case of a blank item or having more than 3 N/A responses in the entire questionnaire, the data of individuals were excluded. Detailed information of CI users is given in Tables 1–2.

For NH participants, inclusion criteria were being at least 18 years old and having no known hearing impairments that could interfere with the study. All procedures of this study were approved by the Ethics Committee of the Marmara University (Protocol No. 09.2022.993) and all participants were informed of the study at the outset of the questionnaire.

Collection of Data

Data were collected online from CI users and NH individuals living in Türkiye, and only data from individuals who met the inclusion criteria were included in the analysis. The study's NH participants were recruited at Marmara University's Audiology Clinic, where the study's researchers were employed. The relatives of the patients who were there to accompany the patient with a complaint of hearing and/or balance problems were first asked questions about whether they had problems with their hearing. The link to the questionnaire was provided to those who met the inclusion criteria and had no known hearing loss. Subsequently, these individuals completed the questionnaire electronically in a setting and at a time that was convenient for them. The recruitment, enrollment, and distribution of forms for CI users were conducted via CI support groups and CI associations. CI users were provided with information about the study and given the option to declare their voluntary participation on the first page of the form.

All CI users were native Turkish speakers, who were able to complete the MuRQoL questionnaire. To maximize the number of participants included in the study and to focus on a general CI population, factors such as the etiology of hearing loss and speech perception abilities were not considered while selecting participants.

TABLE 1. Participant details of cochlear implant users

	n
Type of HL	
Postlingual	101/200 (50.5%)
Prelingual	99/200 (49.5%)
Did not define	14
Hearing modality	
Unilateral	131/214 (61.2%)
Bimodal	68/214 (31.8%)
Bilateral	15/214 (7.0%)
Auditory rehabilitation	
Never received	96/202 (47.5%)
Received or receiving	106/202 (52.5%)
Did not define	12
Music listening modality	
Loudspeakers	53/111 (47.7%)
Wireless audio streaming	37/111 (33.4%)
Headphones over CI microphone	11/111 (9.9%)
Mini microphone	10/111 (9.0%)
Did not define	103

CI, cochlear implant; HL, hearing loss.

TABLE 2. Hearing loss and rehabilitation data of cochlear implant users

	Mean	SD	Minimum	Maximum
Average duration of deafness (yr)	22.8	9.4	3	60
Average duration of HA usage (yr)	13.7	9.3	1	44
Average duration of CI usage (yr)	8.7	5.9	1	24
Average HL age (yr)	11.5	13.16	0	64
Average cochlear implantation age (yr)	24.1	14.98	2	64
Duration of auditory rehabilitation (mo)	68.2	68.1	1	228

CI, cochlear implant; HA, hearing aid; HL, hearing loss.

Procedures

An information form, specifically designed to gather data on hearing loss among CI users, as well as their music listening habits, music education, music enjoyment, demographics, and descriptive information about both CI users and individuals with NH, was distributed to all participants. In addition, the MuRQoL questionnaire was also sent to all participants. In this form, the term "music education" refers to the curriculum-based music education included in compulsory schooling and includes activities such as learning basic music theory, playing the flute, and/or singing at a basic level.

In the demographic information form, the term "auditory rehabilitation" refers to the supportive educational process that includes a variety of speech, language, and listening exercises that can be used both before and after cochlear implantation in Türkiye. The general goal of this process is to support auditory perception skills. In this study, this term does not refer to music rehabilitation or exercises that support music perception and is not used in this sense.

The scores for each question in the frequency scale (FS) of the MuRQoL questionnaire and the corresponding questions in the importance scale (IS) were intersected on a matrix to determine the effect of musical ability on the individual's QoL. Thus, it was determined how and in what direction certain areas of music affect the QoL of the individual. In the light of this information, it was thought that it might be possible to identify individuals in need of music support and to guide music rehabilitation.

The "Music-Related Quality of Life" Questionnaire

In this study, the "Music-Related Quality of Life" questionnaire, which was adapted to Turkish in 2021 was used (Akbulut et al. 2021). The MuRQoL questionnaire is a self-administered instrument designed to assess adult CI users' subjective perception of music, musical engagement, and the potential impact of music on QoL, with the potential to guide and support music rehabilitation Dritsakis et al. (2017a) . The MuRQoL uses a five-point Likert-type scale (never to always) and it consists of two main parts (FS and IS), each with 18 questions split into two subsections. Within the context of the MuRQoL, the term frequency refers to how frequently a particular percept (as presented in items 1 to 18), occurs with a range of 1 = never to 5 = always. The first part which consists of music perception (FS_{MP}, questions 1 to 11) and music engagement subsections (FS_{ME}, questions 12 to 18), called "frequency scale," analyzes how frequently the person is able to perceive and engage with music, therefore assessing subjective music perceptual abilities and experiences about particular perceptual tasks common in music listening and musical activities. The second part which also consists of music perception (IS_{MP}, questions 1 to 11) and music engagement subsections (IS_{ME}, questions 12 to 18), called "importance scale," examines how important the music-related skills and activities covered by the items in the first subsection are to the individual. Each question is rated twice; in the first part according to the frequency of achievement of perceptual skills related to music and in the second part according to the perceived self-importance of the items for the participant in the same order. The scores from each section were added up separately for FS and IS and then divided by the number of questions in each section or subsection (e.g., 18 for FS total and 11 for FS_{ME}) to obtain the final scores used for the analysis.

To evaluate the impact of music on QoL and determine individualized rehabilitation needs, the researchers utilized the matrix presented in Figure 1 from the original study to combine the scores of FS and IS Dritsakis et al. (2017a). When music is considered important in IS, but the corresponding music perception or musical activity item has a low score in FS, music is expected to have a strong and negative impact on QoL. This critical marking of a person for a music perception/musical activity item indicates that the patient needs music rehabilitation, targeting specific areas of music (e.g., singing, pitch perception, etc.) in the rehabilitation program Dritsakis et al. (2017a) .

To determine the neutral/critical score limits for the scores in both parts to be considered normal/high or low and high importance/low importance, normative data obtained from NH participants were used. More details regarding the MuRQoL questionnaire form can be seen in Supplemental Digital Content, http://links.lww.com/EANDH/B497.

Statistical Analysis

Due to the inherent difficulties in creating two groups that are identical in terms of relevant variables, to obtain results that more accurately reflect the auditory difference, the differences between the CI and NH groups were investigated and significant differences were found in terms of education level, music education and interest in music. Therefore, to compare outcomes (e.g., FS and IS scores) between the two groups while controlling for potential confounding variables, two equivalent groups were formed using coarsened exact matching method. The matchit function from the MatchIt package in R is used to perform matching based on the following covariates: age, education level, music enjoyment, music education, and interest in music (Ho et al. 2011). Coarsened exact matching groups observations into strata based on these covariates and then matches within these strata (Iacus et al. 2017). As a result, data of 109 CI users and 118 NH individuals were included for comparison of the two groups. Because the differences between the two groups in terms of other variables were not significant in the within-group analyses for CI users, the data of all 214 CI users who completed the questionnaire were included in the within-group analyses.

Statistical analyses were performed using IBM SPSS 24.0 (SPSS Inc., Chicago, IL). Given that the Likert scale is ordinal, the data were compared using the Mann–Whitney U and Kruskal–Wallis tests. The Spearman correlation analysis was used to calculate correlation coefficients and determine statistical significance when studying the relationship between variables. The results were considered significant when the p values were less than 0.05.

RESULTS

Information on music listening habits, enjoyment of music, music education, and interest in music obtained from the information forms is given in Table 3.

The MuRQoL questionnaire scores of the matched groups were compared using the Mann–Whitney U test. A statistically significant difference was found between the two groups, with the NH group having higher scores in FS total ($U = 2478$, $z = -8.00$, $p < 0.001$), FS_{MP}, ($U = 2342$, $z = -8.28$, $p < 0.001$) and FS_{ME} ($U = 3892$, $z = -5.14$, $p < 0.001$). The two groups did not show any statistically significant difference in terms of the total IS scores ($U = 6226$, $z = -0.41$, $p = 0.677$), IS_{MP} ($U = 5946$, $z = -0.98$, $p = 0.325$), and IS_{ME} scores ($U = 6158$, $z = -0.55$, $p = 0.580$) (Fig. 2).

The educational background was categorized into three categories: "Primary School," "High School," and "University and Higher Education." A Kruskal–Wallis test was performed to analyze the variations in MuRQoL questionnaire scores based on different levels of education. Both groups showed a statistically significant difference in FS total scores (confidence interval [CI]: H(2) = 7.24, $p = 0.027$; NH: H(2) = 9.39, $p = 0.009$), as well as FS_{ME} scores (CI: H(2) = 8.50, $p = 0.014$; NH: H(2) = 7.55, $p = 0.023$), when comparing at least two education groups. The Dunnett T3 test for multiple comparisons revealed that the median value of FS total scores differed significantly between "Primary School"-"High School" (CI: $p = 0.034$, 95% CI = [−1.13 to −0.03]; NH: $p = 0.045$, 95% CI = [−0.01 to 0.67]) and "Primary School"-"University and Higher Education" (CI: $p = 0.044$, 95% CI = [−1.04 to 0.05];

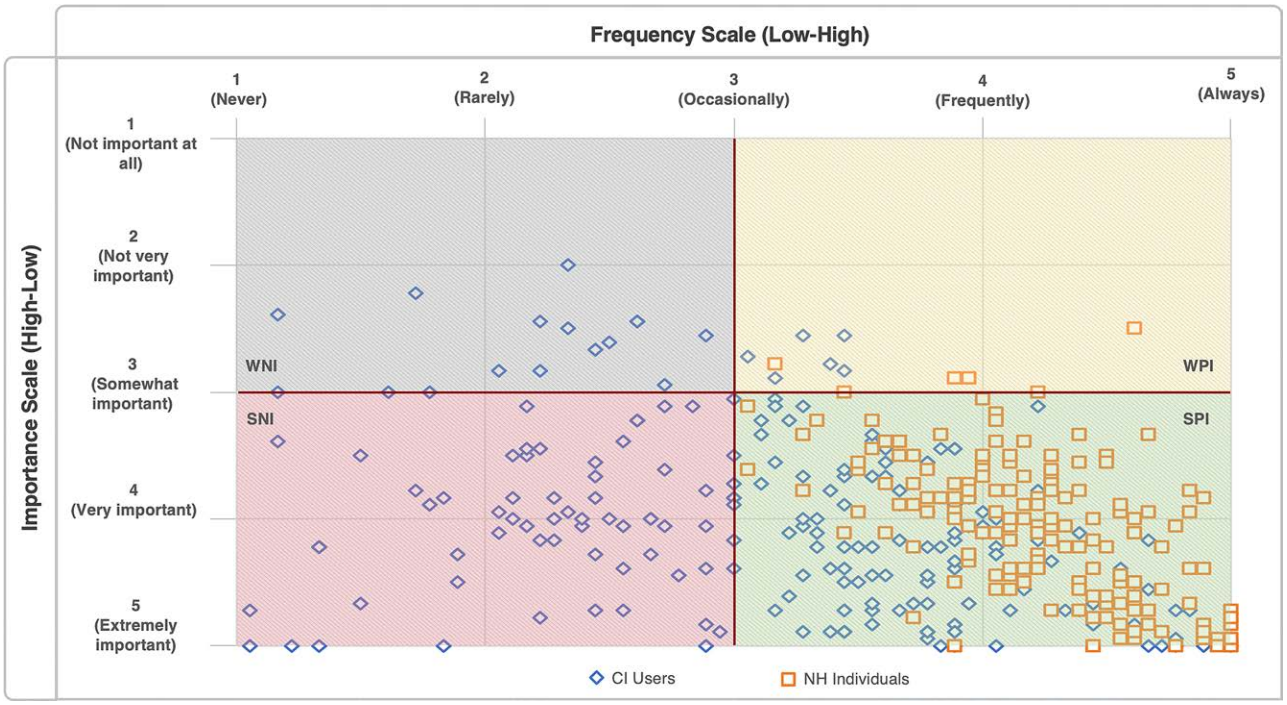

Fig. 1. Matrix of frequency and importance total score combinations for cochlear implant and normal hearing groups. SNI area indicates "critical" scores for clinical rehabilitative purposes. SNI indicates strong negative impact; SPI, strong positive impact; WNI, weak negative impact; WPI, weak positive impact.

NH: $p = 0.007$, 95% CI = [0.14 to 0.74]). There were significant differences in FS_{ME} scores between "Primary School" and "High School" (CI: $p = 0.01$, 95% CI = [−1.43 to −0.16]; NH: $p = 0.006$, 95% CI = [0.10 to 0.70]), as well as between "Primary School" and "University and Higher Education" (CI: $p = 0.045$, 95% CI = [−1.25 to 0.01]; NH: $p < 0.001$, 95% CI = [0.22 to 0.66]). In all comparisons, primary school graduates scored lower. However, there were no significant differences observed in the total scores of IS (CI: $p = 0.071$; NH: $p = 0.151$), IS_{MP} scores (CI: $p = 0.580$; NH: $p = 0.356$), and IS_{ME} scores (CI: $p = 0.320$; NH: $p = 0.630$) when considering different levels of education.

The Spearman correlation analysis showed a weak, yet statistically significant negative correlation between age and MuRQoL among CI users. This statistically significant correlation was specifically observed with FS total scores ($p < 0.001$, $r = -0.242$), FS_{MP} ($p = 0.022$, $r = -0.163$), and FS_{ME} ($p < 0.001$, $r = -0.326$) scores.

For CI users, music education had a significant effect on the MuRQoL scores. Participants who received music education at any point in their lives demonstrated higher FS total scores ($U = 790.5$, $z = -4.41$, $p < 0.001$), FS_{MP} scores ($U = 778.5$, $z = -4.46$, $p < 0.001$), FS_{ME} scores ($U = 973$, $z = -3.7$, $p < 0.001$), IS total scores ($U = 1295.5$, $z = -2.44$, $p = 0.015$), IS_{MP} scores ($U = 1381.5$, $z = -2.11$, $p = 0.035$), and IS_{ME} scores ($U = 1230$, $z = -2.7$, $p = 0.007$).

A Mann–Whitney U test was used to assess if there was a significant difference in MuRQoL scores based on the type of hearing loss. Significant differences were observed only in the FS total scores ($U = 3708$, $z = -3.15$, $p = 0.002$) and FS_{ME} scores

TABLE 3. Music listening habits and demographics of NH participants and CI users

		CI Users (n = 214)	NH Participants (n = 193)
Music listening habits	Never	15 (6.4%)	0
	Rarely	25 (11.3%)	3 (1.5%)
	Sometimes	70 (33.3%)	17 (8.8%)
	Often	52 (24.5%)	81 (42.0%)
	Always	52 (24.5%)	92 (47.7%)
Music enjoyment	Never	12 (6.4%)	0
	Rarely	25 (11.3%)	4 (2.1%)
	Sometimes	70 (33.3%)	13 (6.7%)
	Often	52 (24.5%)	85 (44.0%)
	Always	52 (24.5%)	91 (47,2%)
Music education	26 received (10.3%)		46 received (22.4%)
	188 never received (89.7%)		147 never received (77.6%)
Interest in music	170 have interest in music (80.9%)		179 have interest in music (95.1%)
	44 don't have interest in music (19.1%)		14 don't have interest in music (4.9%)

CI, cochlear implant; NH, normal hearing.

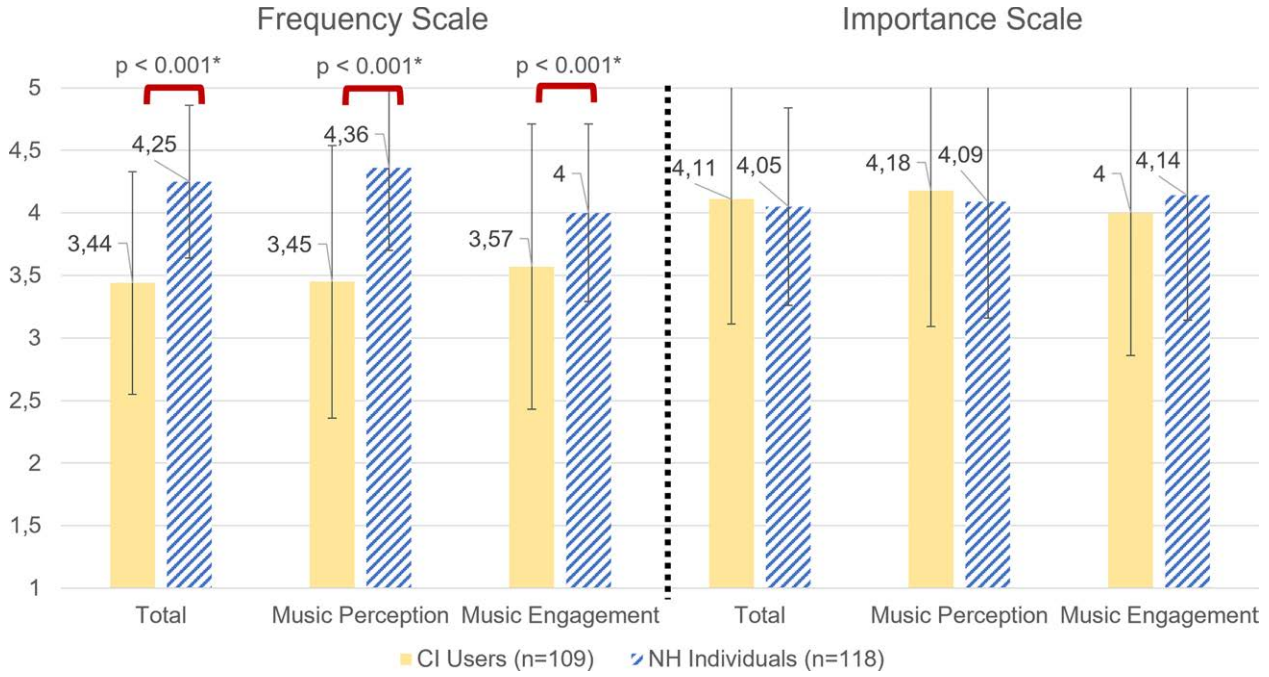

Fig. 2. Comparison of MuRQoL questionnaire scores of matched CI and NH groups. CI indicates cochlear implant; MuRQoL, music-related quality of life; NH, normal hearing.

($U = 2834$, $z = -5.29$, $p < 0.001$), with CI users with prelingual hearing loss scoring higher.

Contrary to expectations, Spearman correlation analysis revealed no significant correlations between the duration of hearing aid use before cochlear implantation and the MuRQoL questionnaire scores of CI users (FS total scores, $p = 0.950$; FS_{MP} scores, $p = 0.996$; FS_{ME} scores, $p = 0.708$; IS total scores, $p = 0.897$; IS_{MP} scores, $p = 0.773$; IS_{ME} scores, $p = 0.846$). However, a weak but statistically significant correlation was observed between FS_{ME} scores and the duration of CI use ($p = 0.029$, $r = 0.163$).

A Kruskal–Wallis test was performed to analyze the differences in MuRQoL questionnaire scores based on hearing modality, which was categorized as unilateral, bilateral, and bimodal. There was a statistically significant difference in the total FS (H(2): 8.82, $p = 0.12$), and FS_{MP} scores (H(2) = 12.59, $p = 0.002$) between at least two groups. The Dunnett T3 test for multiple comparisons revealed that the median FS total scores of unilateral CI users were significantly lower than those of bilateral CI users ($p = 0.014$, 95% CI = [−1.34 to −0.14]). Similarly, the median FS_{MP} scores of unilateral CI users were significantly lower than those of bilateral CI users ($p = 0.002$, 95% CI = [−1.51 to −0.36]), and median FS_{MP} scores of bimodal CI users were also significantly lower than those of bilateral CI users ($p = 0.018$, 95% CI = [−1.30 to −0.11]). There were no statistically significant differences in FS_{ME} scores ($p = 0.263$), IS total scores ($p = 0.084$), IS_{MP} scores ($p = 0.184$), and IS_{ME} scores ($p = 0.668$) based on hearing modality.

The Mann–Whitney *U* test revealed that there was a significant difference in total FS_{ME} scores between CI users who had received or were currently receiving auditory rehabilitation ($U = 4210$, $z = -2.11$, $p = 0.034$), with CI users receiving auditory rehabilitation having higher scores. The Spearman correlation analysis revealed that there was no correlation between the duration of auditory rehabilitation and the scores on the MuRQoL questionnaire for CI users who had received or are currently receiving auditory rehabilitation (FS total scores, $p = 0.880$; FS_{MP} scores, $p = 0.723$; FS_{ME} scores, $p = 0.184$; IS total scores, $p = 0.545$; IS_{MP} scores, $p = 0.420$; IS_{ME} scores, $p = 0.733$).

Lastly, a Kruskal–Wallis test was performed to analyze the variations in the MuRQoL questionnaire scores based on music listening modality. The method used for listening to music, whether loudspeakers, headphones, direct streaming, or mini microphone, did not result in any significant differences in MuRQoL questionnaire scores among CI users (FS total scores, $p = 0.773$; FS_{MP} scores, $p = 0.922$; FS_{ME} scores, $p = 0.472$; IS total scores, $p = 0.825$; IS_{MP} scores, $p = 0.973$; IS_{ME} scores, $p = 0.205$).

The score distributions of the matched NH and CI user groups for the FS and IS revealed that nearly all of the mean scores of NH individuals were more than three for both the FS and IS. Considering that the NH individuals included in the study were reasonably representative of the NH population, scores above or below neutral on both scales would indicate a positive/negative or strong/weak effect, respectively.

When the FS and IS total mean scores of 214 CI users included in the study were intersected on the matrix to see the effect of music on QoL in general, it was observed that music had a strong negative impact on QoL in 67 (31.31%) of the users, a weak negative impact on QoL in 15 (7.01%), a weak positive impact on QoL in 8 (3.73%), and a strong positive impact on QoL in 124 (57.94%). To evaluate the influence of particular aspects of music on QoL and visualize the differences between NH and CI populations, the scores given by both groups in FS and IS were intersected on the matrix proposed by Dritsakis et al. (2017a) for each question (Fig. 1). Furthermore, the FS and IS scores for each question in the matrix were combined to evaluate the individual impact of the many domains measured by the questions on the QoL of CI

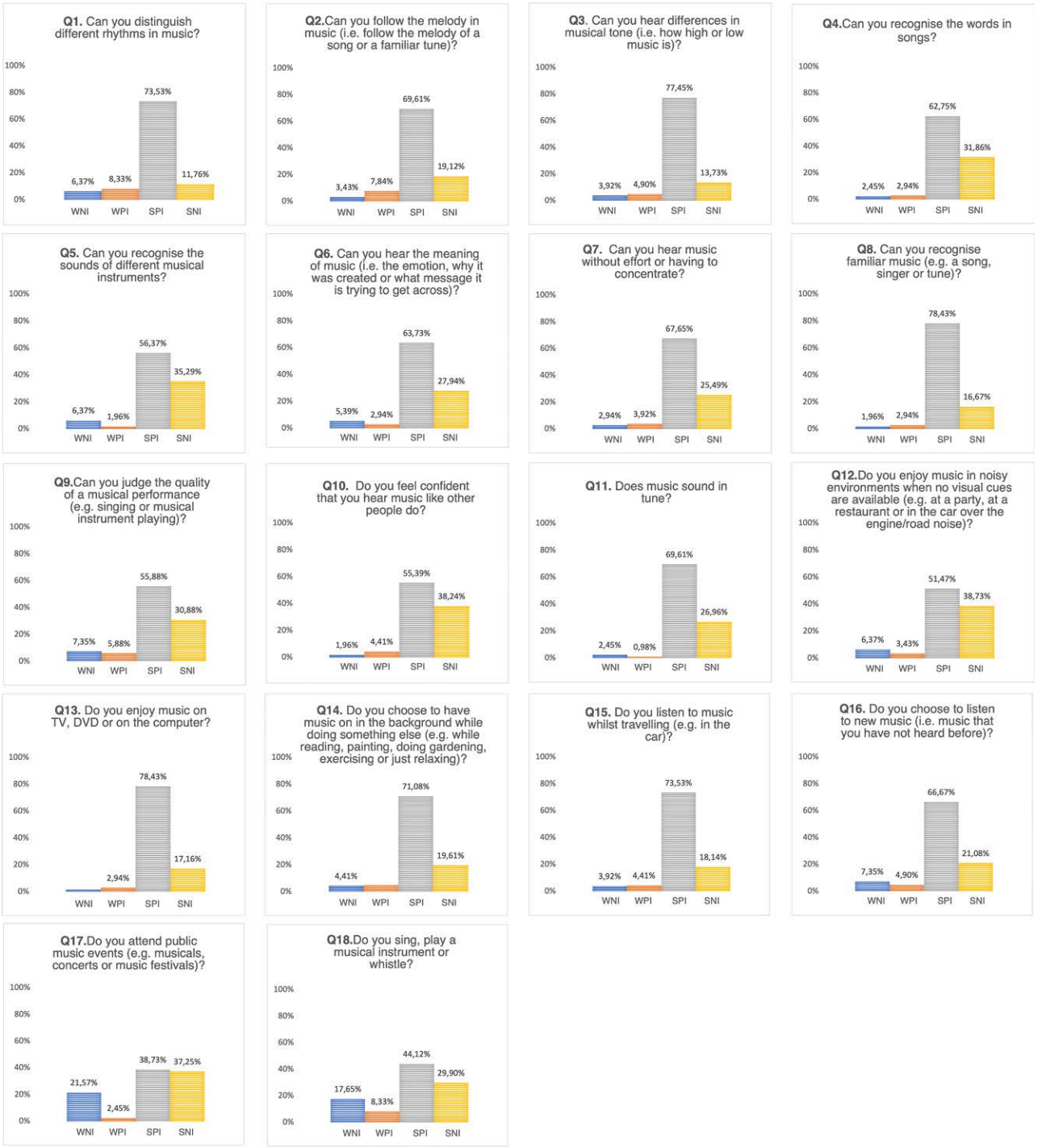

Fig. 3. Percentage representations of the effects of each question in the MuRQoL questionnaire on the quality of life of CI users. CI indicates cochlear implant; MuRQoL, music-related quality of life; SNI, strong negative impact; SPI, strong positive impact; WNI, weak negative impact; WPI, weak positive impact.

users (Fig. 3). Table 4 shows the means and medians of the responses from CI users to the questions in the FS and IS parts of the questionnaire.

DISCUSSION

One of the limitations of many previous studies on music and QoL is that MuRQoL has not been directly assessed. These studies have often been conducted indirectly, usually using generic QoL questionnaires, which seldom address the impact of music as part of QoL to any extent. By directly examining the relationship between subjective music perception, music enjoyment, and QoL, the methodology of our study overcomes the limitations of previous methods and provides a more direct and detailed examination of music in relation to QoL.

Although music-related skills can be assessed with clinical music perception tests, these tests alone may not always be sufficient to assess enjoyment of music and the impact of music on

TABLE 4. Mean and median values of CI users to questions in FS and IS sections of the MuRQoL questionnaire

	Mean ± SD		Median (IQR: Q1–Q3)	
	FS	IS	FS	IS
Q1	3.37 ± 1.07	3.73 ± 1.1	3 (3–4)	4 (3–5)
Q2	3.42 ± 1.12	3.87 ± 1.1	4 (3–4)	4 (3–5)
Q3	3.55 ± 1.16	3.96 ± 0.98	4 (3–4)	4 (3–5)
Q4	2.88 ± 1.12	4.29 ± 0.90	3 (2–4)	5 (4–5)
Q5	2.93 ± 1.23	3.94 ± 1.06	3 (2–4)	4 (3–5)
Q6	3.11 ± 1.24	4.05 ± 1.05	3 (2–4)	4 (3–5)
Q7	3.15 ± 1.22	4.15 ± 1	3 (2–4)	4 (3–5)
Q8	3.6 ± 1.18	4.23 ± 0.88	4 (3–5)	4 (4–5)
Q9	2.92 ± 1.2	3.85 ± 1.11	3 (2–4)	4 (3–5)
Q10	2.89 ± 1.29	4.39 ± 0.96	3 (2–4)	5 (4–5)
Q11	3.2 ± 1.2	4.21 ± 0.90	3 (2–4)	4 (4–5)
Q12	2.77 ± 1.43	3.94 ± 1.07	3 (1–4)	4 (3–5)
Q13	3.81 ± 1.29	4.3 ± 0.90	4 (3–4)	5 (4–5)
Q14	3.56 ± 1.37	4.07 ± 1.07	4 (3–5)	4 (4–5)
Q15	3.69 ± 1.42	4.12 ± 1.04	4 (3–5)	4 (4–5)
Q16	3.35 ± 1.41	3.91 ± 1.13	3 (2–5)	4 (3–5)
Q17	2.36 ± 1.37	3.44 ± 1.24	2 (1–3)	4 (3–5)
Q18	2.62 ± 1.37	3.53 ± 1.29	3 (1–4)	4 (2–5)

FS, frequency scale; IS, importance scale; MuRQoL, music-related quality of life; IQR, interquartile range.

individuals' MuRQoL due to differences in the role and importance of music in their lives. The fact that music perception scores and the individual's enjoyment of music do not always show a strong correlation indicates that the enjoyment of music should be studied together with music perception (Wright & Uchanski 2012). The increasing interest in music in the CI user population and the fact that many users do not feel that they enjoy music sufficiently suggests the importance of measuring the impact of music on their QoL.

Comparison of CI and NH Groups

In terms of IS scores, the lack of a significant difference between the two groups suggests that despite having more difficulty perceiving music, CI users care about music as much as NH individuals. These results are consistent with prior studies that indicate music is important to adult CI users, despite perceptual limitations (Frederigue-Lopes et al. 2015; Dritsakis et al. (2017a); Frosolini et al. 2022).

MuRQoL and Demographics, Age Effect, Music-Related and Audiological Factors

We found that CI users with higher education levels tended to respond with higher FS scores, especially in the FS_{ME}. While the interpretation of this finding is not straightforward, it suggests that individuals who are exposed to a greater amount of music stimuli in schools and engage in more musical activities as their education level increases are likely to have more positive views toward music and musical activities. Similarly, FS and IS scores of CI users, who received regular music education at some point in their lives, were significantly higher. The findings concerning improvements in music perception through music education align with the existing body of research (Cheng et al. 2018). The correlation between the importance of music for CI users and their QoL related to music has not been extensively studied before. However, Bartel et al. (2011) revealed in their research that those who had received music education in the past attributed a significantly greater importance to music in their life. Consistent with this finding, we noted that individuals who had previously undergone music education exhibited higher IS scores. However, in previous studies, music education was used to improve the music perception abilities of CI users. In contrast, our study defines music education as the rudimentary and restricted level of musical instruction included in school curricula, rather than education specifically tailored to improve the music perception of CI users. However, the higher FS scores of CI users who reported getting music education may indicate that even a rudimentary, general music education may improve the development of music perception and foster a good attitude toward music.

Our study revealed a weak negative correlation between the total FS score and age, as well as a weak negative correlation between the FS_{ME} component and age. This suggests that younger users tended to provide higher scores compared with older users. Based on this finding, younger users engage more with music, and these findings can be considered consistent with the literature (Mirza et al. 2003). The combination of the limitations of electrical stimulation and disadvantages related to aging, such as decreased ability for processing temporal envelope and fine structure cues, might result in an impairment in music perception skills. For instance, a study revealed a negative correlation between age and the ability to recognize songs with lyrics, while another study indicated that age plays a significant role in the deterioration of the ability to recognize melodies (Gfeller et al. 2008, 2012). In addition, it has been proven that the musical experiences of CI users can impact their music perception skills. As supported by the negative correlation between increasing age and FS_{ME} in our study, participation in musical activities may decrease with increasing age. Based on these findings, it may be suggested that considering musical experiences during comparisons to reveal age-related changes in music perception skills may provide more accurate results regarding the effects of increasing age and the underlying processes. Last, the variation in music tastes across different age groups may suggest that age-related comparisons can also be influenced by individual music preferences. For instance, the genres of hip-hop and rap, characterized by rhythmic speech,

may be more popular among younger individuals (Bonneville-Roussy et al. 2017). These genres have the potential to impact the perception of music in a positive manner. Our study did not collect data on participants' music preferences, therefore we were unable to evaluate such an effect. We believe that future studies examining the influence of specific musical genres with different structural characteristics could provide valuable and interesting insights into this topic.

When the relationship between questionnaire scores and type of hearing loss was investigated, we found that CI users with prelingual hearing loss had higher FS_{ME} scores compared with those with postlingual hearing loss. This indicates that these users may be more likely to engage with music-related activities. The developmental history and differences in the central and peripheral auditory pathways are an important element contributing to the differences between prelingual and postlingual CI users. This variation arises from factors such as differences in neuronal survival, varying morphological changes in nerve fibers, distinct etiologies, and the duration of auditory deprivation before implantation (Peterson et al. 2010; Limb & Roy 2014; Seyyedi et al. 2014). With the exception of rhythm identification, prelingual CI users typically demonstrate poorer music perception abilities, such as pitch, timbre, and melody, when compared with individuals with NH. Hence, individuals commonly subjectively express dissatisfaction when listening to music with a CI (Looi et al. 2012; Limb & Roy 2014). However, prelingual CI users are believed to have a greater appreciation for music than postlingual CI users. This is because they lack an acoustic musical memory against which they can compare the electrical stimulation signal (Limb & Roy 2014; Fuller et al. 2019). One possible explanation for the increased engagement with music and higher scores in the FS_{ME} subsection among prelingual CI users in our study may be the result of this factor.

Prior studies indicate that bilateral (Veekmans et al. 2009; Polonenko et al. 2017), bimodal (Zhou et al. 2021; Dincer D'Alessandro et al. 2022), and EAS users (Kelsall et al. 2017; Parkinson et al. 2019) have an advantage in terms of music perception and enjoyment after implantation. According to Gfeller et al. (2008), there is a significant correlation between the usage of bilateral CIs and hearing aids in the contralateral ear, and the enjoyment of music with lyrics. In this study, our findings demonstrate that the scores of CI users on the FS_{MP} subsection varied based on the type of auditory stimulation. Furthermore, unilateral CI users scored lower compared with participants who had bimodal and bilateral auditory stimulation, which aligns with previous research in the literature.

A study on children with CIs found that the capacity to perceive musical cues increased with older age at the time of cochlear implantation. These children had better low-frequency hearing before implantation and were able to benefit from it with the use of hearing aids. Hopyan et al. (2012) suggest that having early acoustic hearing in the low-frequency regions at an early stage could serve as a basis for music perception and subsequently enhance the experience with the use of electrical hearing. Our study revealed that there was no statistically significant difference in scores between individuals who used hearing aids before cochlear implantation and those who did not. The gap between our results and the literature may be attributed to the non-homogeneous distribution of age at cochlear implantation, the effectiveness of hearing aids, and the unknown preimplantation-aided thresholds.

Auditory rehabilitation had no significant impact on the questionnaire scores of CI users, with the exception of FS_{ME}. However, it was noted that those who had auditory rehabilitation had slightly higher FS_{MP} scores. Besson et al. (2011) suggest that speech and music share a common system for processing similar auditory characteristics. The complex relationship between language skills, speech perception, and music perception indicates that skill transferability between these domains is complicated. According to Kraus & Banai (2007), shared auditory skills suggest that music and language have similar processing mechanisms. This means that practicing in one domain can enhance skills in the other (Kraus & Banai 2007). However, there are differing opinions regarding the fundamental nature of these enhancements, whether they originate from bottom-up statistical learning or the top-down learning associated with music. The complexity arises from the potential discrepancy between language and music in terms of transfer effects criteria such as precision, emotion, and attention. Music, for instance, may have higher demands for processing precision and emotional benefits than language. Consequently, language skills and speech perception may not always have a beneficial impact on music perception, which could be explained by the complex nature of these circumstances (Patel 2012; Asaridou & McQueen 2013). The higher FS_{ME} scores observed in individuals who underwent auditory rehabilitation were attributed to their lower average age, rather than being directly linked to the auditory rehabilitation itself.

CI users use many methods, including headphones, loudspeakers, and wireless Bluetooth streaming from compatible devices, to engage with music. Each method presents distinct advantages and difficulties. A study found that individuals had greater music perception scores when they listened to music through either loudspeakers or headphones. Conversely, individuals using Bluetooth streaming scored the lowest ratings, raising questions on the efficacy of this method (Lam et al. 2022). Bluetooth streaming may produce artifacts, distortions, and inherent time delays during transmission, which might potentially contribute to diminished performance in music perception (Haifeng et al. 2003). Besides this, the perception of stereo effects is also important in music enjoyment as it contributes to the spatial perception of sound (Choisel & Wickelmaier 2007). Achieving stereo perception remains challenging in free-field listening conditions due to factors like room acoustics, loudspeaker placement, and noise. However, a study conducted by Eshraghi et al. (2020) found that direct audio streaming had a positive impact on the ability of individuals with bilateral CIs to perceive stereo sound, resulting in an enhanced experience of music. With the continuous advancement of CI technology, the utilization and prevalence of wireless audio are increasing, making it more convenient to use. Direct transmission of music to the ear, bypassing room acoustics, has the potential to improve music perception and sound quality. As a result, there may be an improvement in music enjoyment for CI users. In this study, no significant difference was observed in any section of the MuRQoL questionnaire between CI users who used different methods of music listening. We hypothesized that there could be multiple variables contributing to this finding, including variations in the distribution of hearing modalities, the influence of individual or device-specific factors, and the limited amount of data from participants in the music listening modality.

The Impact of Music on QoL • The matrix visualization illustrates the influence of subjective music perception abilities on QoL for both CI users and individuals with NH. It also summarizes the contrast between the two groups. Based on the matrix, approximately 67 out of 214 CI users in our study experienced a strong negative impact of music on QoL in general. Therefore, low FS scores and high importance indicate a critical impact from a rehabilitative perspective in these individuals. These results, consistent with the prior findings reported by Frosolini et al. (2022), indicate a significant need for musical intervention for some CI users, with an evaluative tool available that helps identify those individuals. Moreover, by utilizing the suggested matrix, it became feasible to pinpoint the specific areas in which individuals require interventions for each item. Figure 3 illustrates that the MuRQoL of CI users in our study was significantly affected by various factors. These factors include listening to music in noisy environments, engaging in music-related activities, perceiving music similarly to others, identifying different musical instruments, and recognizing lyrics in songs. All of these factors had a negative effect on the MuRQoL of CI users. A total of 124 out of 214 CI users indicated a strong positive impact of music on their QoL. The correlation between music's positive impact on QoL in CI users who scored highly on the FS subsection aligns with the results of earlier research that examined the connection between music perception and QoL through the assessment of music perception using either objective or subjective measures. When interpreting these rates concerning the impact of music on QoL, it is important to acknowledge that the perception of music and QoL can be influenced by factors associated with the device (such as electrode placement and coverage, sound processing strategy) and/or the individual (such as the etiology of hearing loss, residual hearing, auditory deprivation, cognitive and psychological variations). The study's capacity to draw conclusions about the high rates of CI users experiencing significant positive effects of music on their QoL, or to generalize these rates to the broader CI population, is restricted due to the lack of knowledge on many of the aforementioned aspects.

Clinical Implications

It should be noted that a comprehensive music assessment requires the inclusion of both music perception tests and self-reported questionnaires. However, objective music assessments sometimes require specialized equipment and expertise, consume more time, and frequently fail to offer insights into aspects such as music appreciation or engagement in musical activities. Because music is an acoustic input that can affect the listener's state of mind, self-report questionnaires may be a better way to capture the enjoyment of music and the impact of interventions on the QoL than perceptual tests that assess specific auditory abilities (Dritsakis et al. (2017a). Therefore, despite the limitations and nature of self-report scales, it is recommended that the self-reported questionnaires should be included in clinical assessments in conjunction with perceptual measures such as music test batteries developed for CI users.

By considering particular domains in which CI users have difficulties, it may be possible to increase the effectiveness of music-related therapeutic programs. In fact, the use of a music-related self-report questionnaire, identifying which areas of music have the highest negative impact on people's QoL, may help determine priorities when designing these intervention programs. It is hypothesized that if individuals indicate that a particular area of music perception, in which they lack ability, is of lesser importance to them, the detrimental effects on their QoL will be lessened.

We believe that using a questionnaire that directly evaluates subjective music perception and MuRQoL, in combination with clinical tests measuring music perception, will provide a better understanding of the sensitivity of these questionnaires to measure subjective music perception skills. This approach will also allow for a more comprehensive and thorough assessment by understanding the connection between perceived and measured music perception.

Limitations • Some of the limitations of our study include the lack of data on the performance of CI users (such as implanted hearing thresholds and speech comprehension performance), the etiology, characteristics, and process of hearing loss (such as the amount of residual hearing, progression, hearing aid benefit, duration of auditory rehabilitation and their quality), as well as factors that may affect music perception skills, such as the time spent listening to music. One limitation of our study is that we were unable to apply clinical music perception tests due to the online nature of our sample. As a result, the data collected was primarily subjective, which may not provide a comprehensive and holistic evaluation. Within this particular framework, it is important to note that the measurement of music perception in this study was only based on self-report. This presents an additional constraint, because self-reporting has the potential to either overestimate or underestimate the actual degree of perceptual accuracy. The number of adult bilateral CI users in our study is also limited. Therefore, a larger number of bilateral users is required to ensure a more accurate representation of this group and to provide a more reliable statistical analysis.

Another limitation of our study is the difficulty in forming groups representative of the CI user and NH populations due to inherent difficulties. It is very difficult to create an NH group comparable to CI users by controlling all possible variables such as education level, music education, importance given to music, as well as factors such as socio-economic status, family education level, and forms of musical engagement. Despite the relatively large sample size of our study, we found significant differences between the two groups in several characteristics. Therefore, it was necessary to match the groups before making any comparisons. Also, the inclusion of NH participants in this study was based on a convenience sample of the relatives of patients who accompanied individuals with hearing and/or balance complaints, rather than a broad and representative range of NH listeners. Hence, future research should consider reaching participants not only through online platforms but also through alternative routes to enhance the representativeness of the findings with respect to the broader population in relation to music.

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All procedures of this study were approved by the Ethics Committee of the Marmara University (Protocol No. 09.2022.993) and all participants were informed of the study at the outset of the questionnaire.

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Data are available upon request.

The authors have no conflicts of interest to disclose.

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