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Original Article

The Effects of Music-Based Auditory Training on Hearing-Impaired Older Adults With Mild Cognitive Impairment

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Objectives. The present study aimed to determine the effect of music-based auditory training on older adults with hearing loss and decreased cognitive ability, which are common conditions in the older population.

Methods. In total, 20 older adults diagnosed with both mild-to-moderately severe hearing loss and mild cognitive impairment (MCI) participated. Half of this group were randomly assigned to the auditory training group (ATG), and the other half were designated as the control group (CG). For the ATG, a 40-minute training session (10 minutes for singing a song, 15 minutes for playing instruments, and 15 minutes for playing games with music discrimination) was conducted twice a week for 8 weeks (for a total of 16 sessions). To confirm the training effects, all participants were given tests pre- and post-training, and then a follow-up test was administered 2 weeks after the training, using various auditory and cognitive tests and a self-reporting questionnaire.

Results. The ATG demonstrated significant improvement in all auditory test scores compared to the CG. Additionally, there was a notable enhancement in cognitive test scores post-training, except for the digit span tests. However, there was no statistically significant difference in the questionnaire scores between the two groups, although the ATG did score higher post-training.

Conclusion. The music-based auditory training resulted in a significant improvement in auditory function and a partial enhancement in cognitive ability among elderly patients with hearing loss and MCI. We anticipate that this music-based approach will be adopted for auditory training in clinical settings due to its engaging and easy-to-follow nature.

Keywords. *Aural Rehabilitation; Cognitive Function; Auditory Function; Mild Cognitive Impairment; Age-Related Hearing Loss; Age-Friendly Health Service*

INTRODUCTION

According to the World Health Organization, approximately 55 million people worldwide are living with dementia, with over 10 million new diagnoses each year [1]. The rapid increase in older adults is leading to a significant rise in the number of older individuals diagnosed with degenerative diseases, such as cognitive impairments [2,3]. This trend is causing major health concerns [4] and placing a greater economic burden on many countries tasked with their care.

Since age-related hearing loss has a significantly stronger correlation with reduced cognitive function due to dementia than other related factors in older adults, many recent studies have concentrated on the adverse interaction between these two conditions [5-7]. These studies also underscore the growing importance of addressing residual hearing ability in older adults pro-

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actively and as early as possible. Furthermore, clinicians have proposed that aural rehabilitation is necessary not only for older adults with hearing loss, but also for all patients with impaired cognitive functions, in the hope of potentially mitigating their accelerated hearing and cognitive issues [8,9]. Despite this recognized need, a specific protocol for developing and implementing an aural rehabilitation program for these populations has not yet been established for straightforward application in a clinical setting.

Several previous studies, however, have evaluated the performance of patients with cognitive decline using tests such as digit span, word recall, and story retelling, following the application of music-based auditory training [10-17]. For instance, Bottino et al. [10] found that patients with mild Alzheimer's disease significantly increased the length of their backwards digit span after undergoing training. Similarly, Chu et al. [13] reported higher scores in the word recall test among dementia patients who received aural rehabilitation. Studies that utilized story retelling also demonstrated superior performance in the training group compared to the control group [12,14]. However, the research conducted by Ceccato et al. [12] and Giovagnoli et al. [15] did not reveal any significant changes in the digit span test results before and after rehabilitation. This lack of training benefit was also corroborated by Brotons and Kogor [11] and a study by Lyu et al. [16].

Although it is true that neuroplasticity resulting from auditory training can have a positive impact on cognitive function [17,18], previous studies have been hindered by certain limitations. First, there was an absence of standardized criteria for evaluating auditory and cognitive functions, and for identifying the effects of such training on older adults. Second, only a few studies included a control group without any intervention, leading to confusion about the existence of any rehabilitation effects [12-15]. Third, achieving comparable or consistent results across these studies was challenging due to the varied levels of cognitive function among participants [19,20]. Despite these limitations, an interesting observation is that the rehabilitation effect was greater when cognitive function impairment was less severe [10-16]. Additionally, active interventions, such as singing or playing an instrument, were found to yield greater improvements than passive methods such as simply listening to music [19,20].

Using music as stimuli in auditory training can stimulate a broader range of sensory cells than traditional methods, which typically use only a simple sound tone and/or speech utterances within their frequency range [21]. This results in more extensive brain activation [22]. Patel introduced the Overlap, Precision, Emotion, Repetition, Attention (OPERA) hypothesis [23], arguing that speech and music share networks. Therefore, incorporating music into training could potentially enhance speech processing [24]. Such an approach would necessitate trainees to utilize both analytical and comprehensive processing abilities for pitch, rhythm, harmony, and timbre [25]. Corrigall and Trainor [26] further suggested that an effective program should incorporate various task levels to maximize training effectiveness. However, previous studies have not successfully adapted these specialized rehabilitation methods for older adults with hearing loss and cognitive impairment, nor have they applied these diverse methods across various levels of training. Consequently, this study aims to examine the impact of music-based auditory training on older adults with hearing loss and mild cognitive impairment (MCI), which are both prevalent conditions in the older population. Simultaneously, we aimed to develop a training program that these patients can easily access and use effectively for rehabilitation.

HIGHLIGHTS

- Because the reduced cognitive function due to dementia has a much higher correlation with age-related hearing loss than other related factors in older adults, it is important to address older adults' residual hearing ability in advance.
- Music-based auditory training can stimulate a wide range of frequency and provide extensive brain activation.
- Music-based auditory training provides a positive effect in terms of meaningful change in auditory function as well as in cognitive function in older adults.
- Compared to conventional auditory training, music-based auditory training has the advantage of being interesting and easy to follow for most older adults.

MATERIALS AND METHODS

Participants

First, the G*power 3.1.9 program (Heinrich-Heine-Universität Düsseldorf) was used to identify an appropriate sample size for the study (effect size: 0.5, α: 0.05, and power: 0.95) when having repeated measurement to compare the performance between two groups for a total of three times (pre-test, post-test, and follow-up [FU]). Since six or more subjects were suggested as suitable number, a total of twenty older adults with mild-to-moderately severe sensorineural hearing loss and MCI participated in this study. They participated voluntarily through recruitment flyers from the senior welfare centers in Chuncheon. All the subjects reported they were not taking any drugs influencing their cognitive or central auditory functioning and had no previous experience with auditory or cognitive rehabilitation. Half were then randomly assigned to the auditory training group (ATG), and the half were designated as a control group (CG). Table 1 summarizes the general information on these two groups and the results of their hearing and cognitive screening tests.

Before beginning the experiments, all subjects underwent hearing screening using pure-tone audiometry. Based on the ISO (International Organization for Standardization) criteria for mild-

Table 1. General information and hearing and cognitive screening results of participants in each group

Variable	Age (yr)	Sex (M:F)	Pathology	Hearing thresholds (PTA in dB HL)		Cognitive screening (score)	
				Right ear	Left ear	MMSE-K	K-MoCA
ATG	70.20±3.79	4:6	5 for MCI, 1 for PD	33.25±6.78	35.00±6.97	25.90±1.52	18.70±2.41
CG	70.20±3.12	5:5	5 for MCI, 1 for CI	32.00±4.05	33.88±5.11	26.00±1.63	18.60±2.91

Values are presented as mean±standard deviation.
PTA, pure-tone average (of .5, 1, 2, and 4 kHz); MMSE-K, Korean version of Mini-Mental Status Examination; K-MoCA, Korean-Montreal Cognitive Assessment; ATG, auditory training group; MCI, mild cognitive impairment; PD, Parkinson disease; CG, control group; CI, cerebral infarction.

to-moderately severe hearing loss in older adults over 65 years [27], we confirmed that their hearing thresholds were between 26 and 70 dB HL for four testing frequencies of 500, 1,000, 2,000, and 4,000 Hz, without any air-bone gap. The mean thresholds for the subjects were 32.63 dB HL (standard deviation [SD], 5.47 dB HL) and 33.44 dB HL (SD, 6.16 dB HL) for the right and left ears, respectively. They were also both screened as having above 20 scores on the Korean version of Mini-Mental Status Examination (MMSE-K) (i.e., no dementia) [28] and having below 23 as scores on the Korean-Montreal Cognitive Assessment (K-MoCA) for having a reduced cognitive function [29]. Their group scores were 25.95 (SD, 1.54) for the MMSE-K and 18.65 (SD, 2.60) for the K-MoCA. The scores of each group are noted in Table 1. Neither the results of the pure-tone audiometry nor the results of the cognitive screening tests showed any statistically significant difference between the two groups ($P>0.05$).

All experimental content and procedures for the study was approved by the Institute Review Board of Hallym University (No. HIRB–2020-079). The subjects then signed the written consent form to participate in the study after clearly understanding the study's purpose and procedures.

Content of a music-based auditory training program

The music-based auditory training in each session of the study consisted of singing a song, playing an instrument, and participating in a music discrimination game for auditory concentration. While detailed techniques of the training were recomposed based on previous studies [10-12], auditory-visual materials were used. Visual data, such as lyrics, musical notes, and task objectives were presented using a screen of beam projector (MX25, BenQ Corp.) connected to a tablet PC (Surface Pro 7, Microsoft Corp.). Audio materials, i.e., music and instrumental sounds, were presented on Bluetooth speakers (ND8550G Model, LG Co.) connected with the tablet PC that had adjustable volume control, so the subjects could hear them at the most comfortable level.

For the singing training, popular songs for older adults were chosen from various frequency bands that were acoustically analyzed using the Praat software (ver. 4.2.17; https://www.pratt.org). Training content included singing along with a song [11,13, 16,19,20], finger tapping with a song [20], clapping hands with the song [12,20], acting on its words while listening to music [15], and making a double motion between two hands while listening to the music [12]. Training was also gradually carried out at more difficult levels, adjusting by degree based on the music tempo and complexity of the task.

In the musical instrument training, instruments familiar for playing (e.g., tambourine, castanet, cymbals, Korean traditional percussion) were selected. Based on the previous studies, the specific content of the training included a quiz activity for naming the instrument just by listening to the introduction and listening to diverse instrument sounds [14,15], playing the instrument freely in the context of the drumbeat or melody by change in the instrument [12-15,19,20], and giving particular numbers to the participants and telling them to clap their hands or play the instrument only when the trainer called out the instrument or the number, and playing by changing the particular number and the instrument [12,13]. The degree of training difficulty was gradually increased, as the sessions proceeded, the same as had occurred in the singing training. The training was also adjusted for beat speed, melody complexity, length of naming interval, and task complexity.

For music discrimination training to improve the auditory attention paid to music, the trainer's voice (also known as the target stimulus) was provided together with the music as background noise. For instance, while listening to music in which the trainer's voice was compiled, the subjects were required to pick up the color card on the table when the name of a relevant card was heard from five different color cards of choice [13] or put the presented card in proper order. Further, if the subject's number and color name was heard during the music replay, it was also included in the training to find the five color cards hidden beforehand and carry out the simple physical movement that was written on the card [12]. Like the other trainings, the difficulty level for the training was increased gradually, as the session proceeded and was controlled by using task complexity, music speed, and a signal-to-noise ratio (e.g., +10 and +20 dB SNR).

Training protocol and outcome measures

To verify the effect of the music-based auditory training, the current study conducted the various auditory and cognitive function tests three times, e.g., pre- and post-training and again 2 weeks after the training (FU) had completed. To avoid learning effects, however, different lists were used within the same evaluation

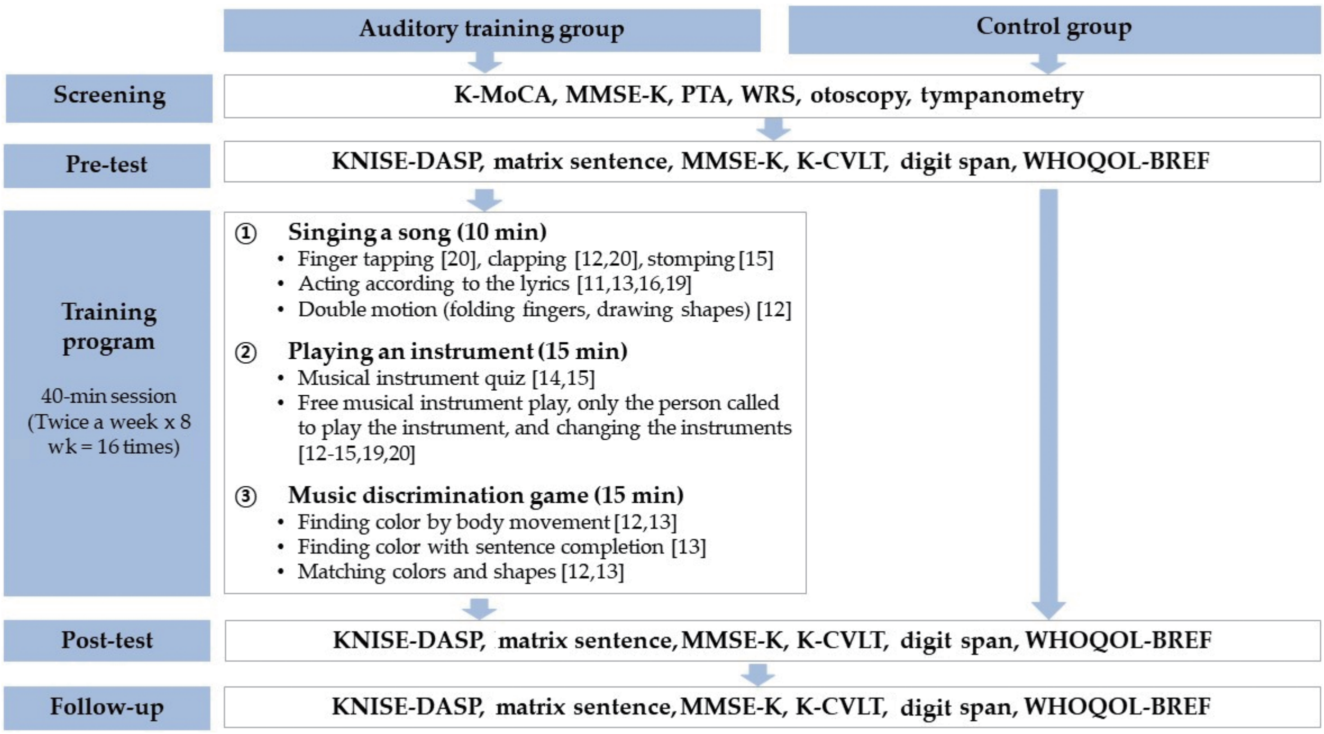

Fig. 1. A schematic presentation of the music-based auditory training protocol. After conducting six screening tests as the inclusion criteria specified, evaluations were conducted at three time points (pre-training, post-training, and then 2 weeks after the training) for both the auditory training group (ATG) and the control group (CG). The evaluation tools consisted of consonant-vowel identification, sentence recognition under both quiet and noise background conditions, sentence memory and sequence, connected speech, memory of digits, and questionnaires. The ATG participated in 40-minute training sessions twice a week for 8 weeks. The training components consisted mainly of singing a song, playing musical instruments, and music discrimination, while also including various games using auditory-visual formats. Each phase of the training became more difficult and complex. K-MoCA, Korean-Montreal Cognitive Assessment; MMSE-K, Korean version of Mini-Mental Status Examination; PTA, pure-tone average; WRS, word recognition score; KNISE-DASP, Korea National Institute for Special Education-Developmental Assessment of Speech Perception; K-CVLT, Korean California Verbal Learning Test; WHOQOL-BREF, Korean version of the World Health Organization Quality of Life Assessment Instrument Short Form.

tool according to the testing time. Fig. 1 summarizes the training procedures and the evaluation used in the current study. All subjects in the ATG received three types of music-based auditory training (e.g., singing, playing a musical instrument, music identification game) for 10, 15, and 15 minutes, respectively, in the same order and conditions. The reason why the order of training was selected as singing, playing a musical instrument, and music discrimination game was to proceed sequentially from easy to difficult, from easy to participate to those that require concentration [17].

In terms of the detail of the test battery, vowel and consonant identification, sentence recognition (i.e., scoring the correct number of complete sentences and target words), sentence memory and sequence, and connected speech tests were all included. All were subordinate tests of the Korea National Institute for Special Education-Developmental Assessment of Speech Perception (KNISE-DASP) [30]. A Korean matrix sentence test [31] was also given using background noisy conditions (i.e., +6 dB SNR). The MMSE-K [28], Korean California Verbal Learning Test (K-CVLT) (including the immediate word recall and delayed word recall) [32], and forward and backward digit span was included as a viable tool to assess the subjects' cognitive ability. Finally, to identify any subjective change in the quality of life from the music-based auditory training, the Korean version of the World Health Organization Quality of Life Assessment Instrument Short Form (WHOQOL-BREF) [33] was applied to all the participants. Individual data of the baseline results of all these tests were provided in the Supplementary Table 1.

For the most successful training, ten subjects in the ATG were divided into two groups of five people each. The reason for setting it up as a small group was to have a sense of belonging without any dropouts for a long training period. However, rather than a fixed group, training slots were set with five trainees in the morning and another five ones in the afternoon, and thus subjects participated in their preferred time. They all actively participated in the training for 40 minutes per a week (with a short break if the participants asked for one), twice each week for 8 weeks (for a total of 16 sessions). The training was conducted by a researcher with major in audiology who graduated from undergraduate and master's degrees, while having a relevant clinical certification.

The researcher who is the first author of the manuscript, formally completed the auditory training course.

Statistical data analysis

A total of 13 variables from the auditory (e.g., consonant/vowel identification, complete sentence, target words, speech recognition in noise, sentence memory/sequence, connected speech) and cognitive tests (e.g., immediate/delayed recall, forward/backward digit span, MMSE-K) and a subjective assessment of quality of life (e.g., WHOQOL-BREF) were statistically analyzed using a repeated measure two-way ANOVA to determine whether the test scores, dependent variables, were significantly different for the three testing times (pre-, post-, and FU), that were the independent variables within the two groups (ATG and CG). In addition, a Bonferroni correction was applied, where possible. The statistical analysis program, IBM SPSS software ver. 25 (IBM Corp.) was used with the $P<0.05$ criterion.

RESULTS

The results of the pre-, post-, and FU tests are displayed in Fig. 2, along with a comparison of the mean and standard deviation between the ATG and CG groups. The statistical outcomes in terms of the main effects for each group, the testing times, and their interactions are then summarized in Table 2.

Fig. 2 shows that the ATG group outperformed the CG group in vowel identification. Following the training, the ATG group's vowel identification significantly improved by approximately 9% (Fig. 2A). This improvement was also significantly sustained in the FU test conducted 2 weeks later ($P<0.05$). In contrast to vowel identification, no significant difference was observed between

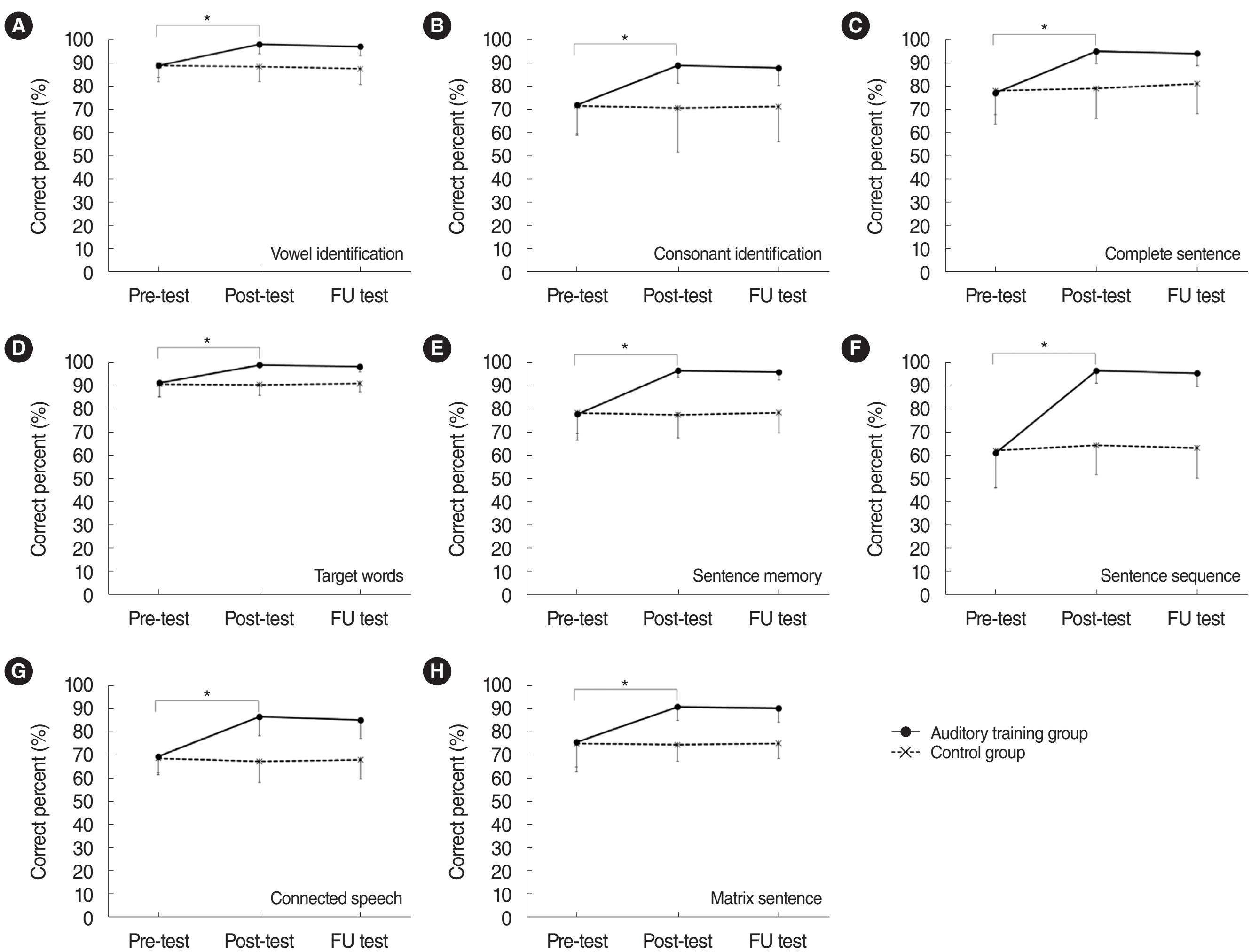

Fig. 2. A performance comparison of eight auditory tests between two groups as a function of the testing time (pre-test, post-test, and follow-up [FU] test): (A) vowel identification, (B) consonant identification, (C) complete sentence, (D) target words, (E) sentence memory, (F) sentence sequence, (G) connected speech, (H) sentence recognition in background noise using a matrix. A solid line with closed circles refers to the auditory training group, and a dashed line with X refers to the control group. *Denotes statistical significance at $P<0.05$.

Table 2. Results of two-way repeated-measures analysis of variance three test points (pre-, post-, and follow-up tests), and groups (ATG and CG)

Measurement		Variable	*df*	Mean square	F	*P*-value
KNISE-DASP	Vowel identification	Group	1	604.965	8.362	0.010*
		Test time	2	101.356	7.889	0.001**
		Group×test time	2	151.241	11.772	0.000***
	Consonant identification	Group	1	2,080.937	4.378	0.051
		Test time	2	417.893	24.012	0.000***
		Group×test time	2	494.540	28.416	0.000***
	Complete sentence	Group	1	1,306.667	5.600	0.029*
		Test time	2	635.000	12.424	0.000***
		Group×test time	2	411.667	8.054	0.001**
	Target words	Group	1	440.104	12.570	0.002**
		Test time	2	90.729	9.222	0.001**
		Group×test time	2	92.604	9.413	0.001**
	Sentence memory	Group	1	2,163.842	12.009	0.003**
		Test time	2	545.781	47.922	0.000***
		Group×test time	2	587.832	51.614	0.000***
	Sentence sequence	Group	1	6,684.270	20.231	0.000***
		Test time	2	2,247.075	43.865	0.000***
		Group×test time	2	1,851.593	36.145	0.000***
	Connected speech	Group	1	2,299.090	14.547	0.001**
		Test time	2	393.676	25.237	0.000***
		Group×test time	2	515.953	33.075	0.000***
Korean matrix sentence test (+6 dB SNR)		Group	1	1,706.667	9.059	0.008**
		Test time	2	360.150	26.101	0.000***
		Group×test time	2	381.817	27.672	0.000***
MMSE-K		Group	1	84.017	19.995	0.000***
		Test time	2	12.517	27.036	0.000***
		Group×test time	2	22.817	49.284	0.000***
K-CVLT	Immediate recall	Group	1	32.267	9.680	0.006**
		Test time	2	11.817	14.771	0.000***
		Group×test time	2	7.117	8.896	0.001**
	Delayed recall	Group	1	88.817	33.657	0.000***
		Test time	2	31.017	35.561	0.000***
		Group×test time	2	20.617	23.637	0.000***
Digit span	Forward digit	Group	1	16.017	6.607	0.019*
		Test time	2	0.817	1.785	0.182
		Group×test time	2	2.617	5.721	0.007**
	Backward digit	Group	1	3.750	3.101	0.095
		Test time	2	0.817	3.219	0.052
		Group×test time	2	0.950	3.745	0.033*
WHOQOL-BREF		Group	1	13.939	0.075	0.788
		Test time	2	99.950	6.411	0.004**
		Group×test time	2	13.256	0.850	0.436

ATG, auditory treatment group; CG, control group; KNISE-DASP, Korea National Institute for Special Education-Developmental Assessment of Speech Perception; SNR, signal-to-noise ratio; MMSE-K, Korean version of Mini-Mental Status Examination; K-CVLT, Korean California Verbal Learning Test; WHOQOL-BREF, Korean version of the World Health Organization Quality of Life Assessment Instrument Short Form.
*$P<0.05$, **$P<0.01$, ***$P<0.001$.

the two groups in terms of consonant identification ($F(1,28)=4.378$, $P=0.051$) (Fig. 2B). Despite the approximately 18% difference in scores between the two groups, the standard deviation for the CG group was notably high at 19% (Figs. 2 and 3). While no significant differences were detected between the groups, an improvement in scores over time was noted in the ATG group. In the FU test, the ATG group also maintained a significantly high score of 87.6% ($P<0.05$).

In the sentence recognition tests, both the completed sentences and target words demonstrated statistically significant differences between the groups and across the testing times, as detailed in Table 2. For the completed sentence test, the pre-test results for the ATG and CG were comparable, at 77% and 78% respectively (Fig. 2C). Following the training, the ATG's perfor-

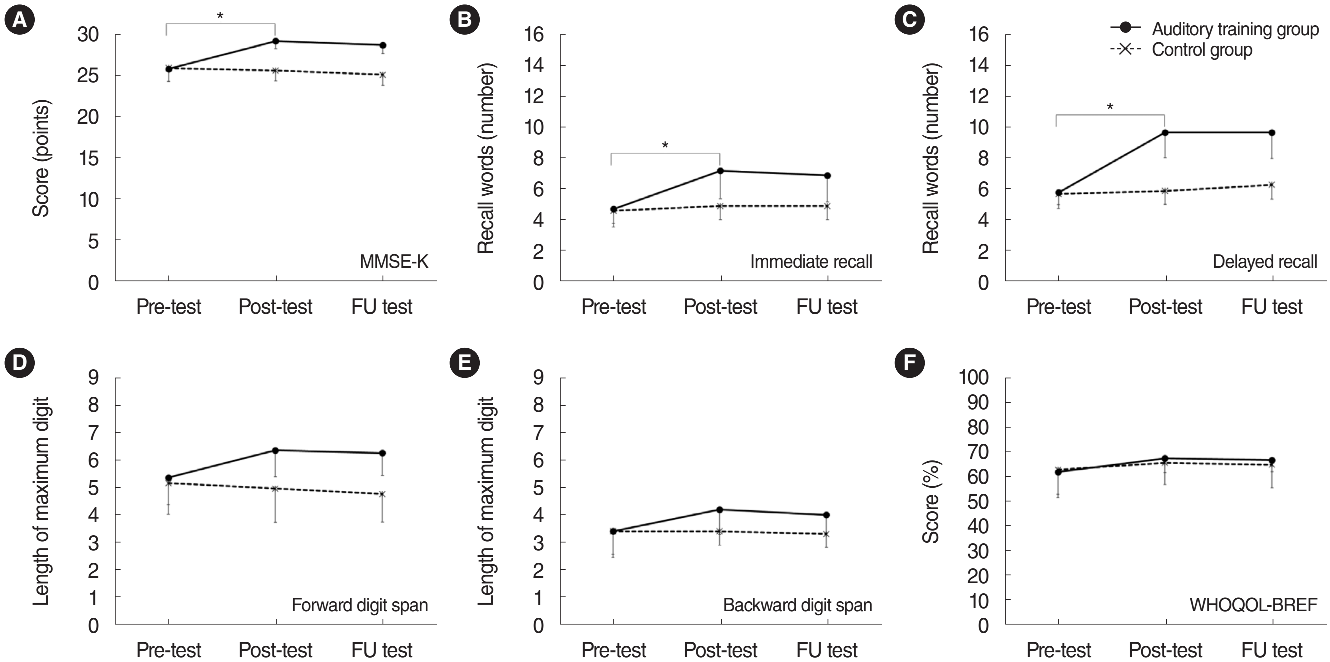

Fig. 3. A performance comparison of five cognitive tests and one subjective questionnaire measuring the quality of life between the two groups as a function of the testing time (pre-test, post-test, and follow-up [FU] test). (A) Korean version of Mini-Mental Status Examination (MMSE-K), (B) immediate recall of Korean California Verbal Learning Test, (C) delayed recall of Korean California Verbal Learning Test, (D) forward digit span test, (E) backward digit span tests, (F) Korean version of the World Health Organization Quality of Life Assessment Instrument Short Form (WHOQOL-BREF). A solid line with closed circles refers to the auditory training group, and a dashed line with X refers to the control group. *Denotes statistical significance at $P<0.05$.

mance improved to 95%, and impressively, it remained at 94% even after a 2-week period ($P<0.05$). Conversely, the target task required the identification of specific words within the sentence, rather than the correction of the entire sentence. As such, both groups achieved high scores of 90% or more, even in the pre-test (Fig. 2D). After the training, the ATG demonstrated a significant improvement of 8% and maintained similar scores after a 2-week period ($P<0.05$).

In the sentence memory (Fig. 2E) and sentence sequence tests (Fig. 2F), a statistically significant difference was observed between the groups and across the testing times (Table 2). For instance, the sentence memory score of the ATG group significantly increased from 77.78% to 96.51% following the training, maintaining an improved score of 95.87% in the FU test ($P<0.05$). In contrast, the scores of the CG group remained approximately 78% throughout the testing times.

Interestingly, the score for the sentence sequence saw a significant increase of 35% or more following the training in ATG. This score was maintained, demonstrating a substantial difference with a P-value of less than 0.001 between the groups and testing time (Table 2). Fig. 2G and H present the results of the connected speech test and matrix sentence test at 6 dB SNR, respectively. Both tests exhibited an increase in scores by 18% and 16%, respectively, in the post-test compared to the pre-test results for ATG. These improved scores were still significantly maintained after a period of 2 weeks ($P<0.05$).

In Fig. 3, line graphs are presented for five cognitive tests and one questionnaire, comparing groups over various testing times. In Fig. 3A, a significant difference is evident in the MMSE test results between the groups ($F(1,18)=19.995$, $P<0.001$) and across the testing times ($F(2,36)=27.036$, $P<0.001$). Although the ATG's improvement score was approximately 3–4 points higher than the CG's, this difference was not as substantial as the results of other tests. Nevertheless, the improvement score was significant ($P<0.05$). In comparison to the CG, where the average across three testing times was five recall words, the ATG demonstrated a significant difference in the immediate recall on the K-CVLT test. This shifted from approximately 4.6 words in the pre-test to 7.2 words in the post-test (Fig. 3B). This result was sustained at 6.9 words in the FU test ($P<0.05$). For the delayed recall test, the ATG exhibited superior memory performance, recalling about four more words after the training (Fig. 3C). This demonstrated a statistically significant difference between the groups ($F(1,18)=33.657$, $P<0.001$) and across the testing times ($F(2,36)=35.561$, $P<0.001$).

In contrast, for the digit span, there was a statistically significant difference in the forward digit between the ATG and CG ($F(1,18)=6.607$, $P=0.019$), but no difference was observed across the three different testing times ($F(2,36)=1.785$, $P=0.182$). In other words, although the ATG showed an improvement of 1 digit length with the training, this finding was complicated by the fact that the CG had a mean and standard deviation of 5 digits and 1.25, respectively (Fig. 3D). Moreover, the backward digits did not demonstrate any significant difference between the groups ($F(1,18)=3.101$, $P=0.095$) or across the testing times ($F(2,36)=3.219$, $P=0.052$). Both groups started with 3.4 digits on the pre-test, but only the ATG showed a slight increase to 4.2 after the training (Fig. 3E), which did not constitute a statistically significant change.

Finally, the results of the WHOQOL test did not show a significant difference between the groups (Fig. 3F). Upon applying a Bonferroni correction to account for the difference in testing time, a significant difference of approximately 4 points was observed between the pre-test and post-test results ($P=0.024$). However, this significance was not maintained in the FU test ($P>0.05$).

DISCUSSION

The present study investigated the effect of music-based auditory training on older adults (over 65 years) who had hearing loss and MCI. The ATG group, which consistently received the 40-minute training for 8 weeks, showed a meaningful change in overall auditory function including phoneme ability and word-level identification, sentence recognition ability, and cognitive function in sentence-level working/short-term memory and word-level long-term memory. When composed and delivered systematically, this training can provide benefits for auditory and cognitive function. This implies the need to clinically emphasize the importance of music-based auditory training in the future for older adults who have hearing loss and reduced cognitive function.

Auditory training is primarily based on the concept of auditory neuroplasticity [17]. Among the various methods, auditory training that incorporates music is recognized for its ability to stimulate a broader range of cortical and subcortical areas compared to traditional auditory training. This approach not only improves verbal and auditory skills, but also improves emotional sensitivity and recognition [34]. Previous research utilizing a neuroscientific approach to study the effects of music training on auditory treatment in older adults has confirmed a reduction in neural timing delays through the processing of rapidly changing auditory information [35]. These studies also report a positive enhancement in the perception of word sounds, directionality, discrimination, and even cognitive ability among hearing-impaired subjects [25,36].

In the present study, we conducted eight different tests to assess changes in auditory function. After 8 weeks of training, we observed an improvement of approximately 18%–20% (Fig. 2). Despite the statistically significant differences, vowel identification (Fig. 2A) and target words (Fig. 2D), which initially had high baseline scores, demonstrated an increase of less than 10%. Most notably, the assessment that exhibited the most significant training effect revealed a substantial difference of about 38% in the post-test between the two groups in the sentence sequence. This outcome is supported by Patel's OPERA hypothesis, which posits that musical training enhances the neural encoding of speech due to improved attention through music activity [23,24]. In other words, it could be possible to compare the auditory encoding demands imposed by musical training and speech perception [23].

In this study, we trained participants in instrumental play and auditory attention using word-level referents, thereby minimizing the use of contextual clues. This type of training elicited auditory feedback through the activity of singing along while simultaneously performing tasks. Among the various tasks, some were designed to utilize the subjects' substantial cognitive resources by establishing immersive listening for interference. The comprehension stage inherently involves auditory ability, which is a component of cognitive function [37]. Consequently, the participants in this study demonstrated a general improvement in both auditory and cognitive functions after undergoing the training. It appears that the training also increased their overall comprehension ability.

However, although there was a statistically significant difference, the effect on vowel identification (Fig. 2A) and target words (Fig. 2D), which initially had high baseline scores, increased by less than 10%.

Compared to the immediate recall test results, the delayed recall test results demonstrated an increase of approximately four words in the ATG after 8 weeks of training. In other words, the training had a greater impact on tests of slightly lower difficulty. This pattern was also observed in digit tests. Previous studies investigating the relationship between music training and working memory have found that subjects who underwent music training did indeed improve their working memory [38,39]. Moreover, a study by Janata et al. [22] used functional magnetic resonance imaging to confirm the activation of the subjects' cortical and subcortical areas. They observed activation in the area associated with working memory management, thereby demonstrating a direct relationship between music training and working memory [22].

Generally, older adults with hearing loss struggle to accept and process auditory information efficiently [40]. As a result, they often rely on inferences for various meanings or nonverbal communication to recover the lost auditory information [41]. This process consumes a significant portion of their cognitive resources, creating a larger cognitive load in their already complex auditory environment [42]. The cognitive retrieval of auditory information delays the reliance on sensory memory, leading to further loss of auditory information in a complex environment [42,43]. This was corroborated by the results of the backward digit test, which did not yield significant results in the current study. In other words, regardless of whether training was conducted or not, long-term memory, a higher-order system of the auditory system, had a detrimental effect [44].

The current study demonstrated that a diverse range of music and task execution positively influenced the subjects' cortical activity and their working memory capabilities. Training that involved playing an instrument and focusing on its sound amidst complex musical situations, while simultaneously concentrating on the researcher's voice embedded in the music, positively impacted the subjects' working memory management. This finding aligns with previous research conducted by Janata et al. [22]. Moreover, the training course, which encompassed tasks from three different types of training, appears to have enhanced the participants' efficient use of their working memory's cognitive resources and improved their executive function. From the perspective of music rehabilitation combined with auditory and cognitive training, the overall cognitive function of the subjects in this study did indeed improve. This improvement likely boosted performance in their higher cognitive systems, while simultaneously reducing cognitive load.

Unfortunately, the music-based auditory rehabilitation did not conclusively yield an effect on the participants' overall quality of life. The WHOQOL-BREF questionnaire, which was used to evaluate participants' overall quality of life, contains five scales: general health, physical health, psychological, social relations, and environmental areas [33]. This questionnaire focuses on the subjects' perceptions of their lives over the past 2 weeks. However, several of the specific questions could not feasibly be altered by an 8-week music-based auditory training. Examples include questions such as "How healthy is the residential environment you are living in?," "How do you rate your current means of transportation?," or "Do you have sufficient funds to meet your needs?" [33].

Meta-analysis studies examining the impact of music rehabilitation on older adults with dementia have primarily focused on psychological factors, such as anxiety or depression. However, this study, which uniquely utilized a variety of testing instruments to assess diverse scales, yielded a different outcome. Furthermore, given the high correlation between depression and cognitive impairment in older adults, some studies have included subjects without diagnosed depression, as well as subjects with only MCI [45]. In our study, we required self-reporting on the presence or absence of depression during the screening test, and none of the subjects reported depression. Instead, this meta-analysis focused on older adults with dementia [46,47], which inevitably limited the scope of psychological changes resulting from rehabilitation when compared to subjects with only MCI. The fact that the WHOQOL-BREF questionnaire, which assess the overall quality of life, measured diverse scales—in addition to the limited changes in psychological factors—may explain the insignificant interaction effect between these groups. Therefore, it is believed that the results of this study were influenced not only by the effect of music-based auditory training, but also by differences arising from various external and internal variables [48].

The present study has several limitations. First, although the number of participants included in each group exceeded the threshold for statistical verification in G*Power, the sample size of only 10 individuals is too small to be generalized to an entire population. Secondly, the training period of 8 weeks may not have been sufficient to fully understand the impact of long-term rehabilitation performance. For instance, in the case of digit span tests that did not yield a statistically significant difference, it is plausible that a longer training period could reveal a difference. To discourage participants from withdrawing from the study, the period from rehabilitation to FU was kept to a brief 2 weeks. Fortunately, most of the test results indicated that performance was significantly maintained. However, it will be necessary to confirm whether performance can be sustained in some of the various tests evaluated in this study through future research. Lastly, the music-based rehabilitation used in this study appears to be quite broad. Given that our rehabilitation approach incorporated a variety of activities, it is challenging to identify the specific impact of each component on auditory and cognitive functions. Future studies could investigate the effects of these individual factors, identify which ones were ineffective, or determine whether significant effects were observed when these factors were combined. Such an investigation could offer deeper insights into the underlying mechanisms of music rehabilitation.

The implementation of an 8-week auditory training program, based on engaging and easy-to-follow music, was conducted for 10 older adults with MCI and hearing loss. It was confirmed that this approach had a significant impact on hearing and cognitive function when compared to the control group. Future studies are anticipated to further refine and standardize this music-based method, with the expectation that it will become widely utilized for auditory training in elderly patients within a clinical setting.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIALS

Supplementary materials can be found online at https://doi.org/10.21053/ceo.2023.00815.

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Supplementary Table 1. Raw data of baseline (pre-test) for all 14 tests in 20 subjects (10 in the ATG and 10 in the CG)

Subject		KNISE-DASP							Matrix sentence	MMSE-K	K-CVLT		Digit span		WHOQOL-BREF
		Vowel	Consonant	Complete sentence	Target words	Sentence memory	Sentence sequence	Connected speech			Immediate recall	Delayed recall	Forward	Backward	
ATG	1	90.48	80.00	80.00	97.50	79.37	55.56	75.00	80.00	28.00	5.00	7.00	6.00	3.00	51.83
	2	85.71	53.33	90.00	95.00	80.95	44.44	67.86	88.00	27.00	7.00	7.00	6.00	4.00	68.55
	3	85.71	83.33	60.00	80.00	58.73	44.44	60.71	76.00	24.00	5.00	5.00	3.00	2.00	60.00
	4	100.00	66.67	90.00	95.00	80.95	77.78	67.86	64.00	25.00	3.00	5.00	6.00	3.00	63.88
	5	95.24	86.67	60.00	85.00	73.02	66.67	67.86	92.00	26.00	4.00	5.00	5.00	4.00	63.62
	6	85.71	86.67	80.00	87.50	90.48	88.89	75.00	84.00	28.00	5.00	6.00	8.00	4.00	74.31
	7	80.95	56.67	90.00	97.50	82.54	66.67	78.57	58.00	27.00	4.00	6.00	5.00	5.00	54.69
	8	85.71	73.33	70.00	90.00	82.54	44.44	57.14	72.00	25.00	6.00	6.00	5.00	2.00	59.50
	9	80.95	60.00	60.00	92.50	71.43	55.56	64.29	54.00	24.00	4.00	6.00	4.00	3.00	76.52
	10	100.00	70.00	90.00	97.50	77.78	66.67	75.00	82.00	25.00	4.00	5.00	6.00	4.00	49.29
CG	11	85.71	83.33	60.00	80.00	58.73	44.44	75.00	76.00	28.00	5.00	6.00	5.00	2.00	52.02
	12	85.71	53.33	70.00	85.00	74.60	44.44	60.71	72.00	26.00	4.00	6.00	4.00	4.00	62.79
	13	100.00	83.33	90.00	97.50	95.24	77.78	67.86	84.00	26.00	5.00	6.00	6.00	4.00	53.21
	14	90.48	80.00	70.00	92.50	73.02	66.67	75.00	80.00	25.00	4.00	7.00	5.00	3.00	57.14
	15	85.71	70.00	90.00	97.50	92.06	88.89	60.71	78.00	26.00	4.00	4.00	5.00	4.00	62.07
	16	85.71	66.67	90.00	90.00	77.78	66.67	60.71	80.00	25.00	6.00	7.00	6.00	4.00	79.33
	17	90.48	50.00	80.00	95.00	66.67	55.56	60.71	68.00	24.00	5.00	6.00	4.00	2.00	57.69
	18	95.24	83.33	80.00	90.00	90.48	55.56	78.57	64.00	27.00	5.00	5.00	5.00	4.00	86.79
	19	85.71	63.33	70.00	90.00	73.02	44.44	71.43	54.00	24.00	3.00	5.00	6.00	4.00	55.76
	20	85.71	80.00	80.00	95.00	80.95	77.78	71.43	88.00	29.00	5.00	5.00	6.00	3.00	64.55

ATG, auditory treatment group; CG, control group; KNISE-DASP, Korea National Institute for Special Education-Developmental Assessment of Speech Perception; MMSE-K, Korean version of Mini-Mental Status Examination; K-CVLT, Korean California Verbal Learning Test; WHOQOL-BREF, Korean version of the World Health Organization Quality of Life Assessment Instrument Short Form.