Effect of Hearing Rehabilitation Therapy Program in Hearing Aids Users: A Prospective Randomized Controlled Study

Running title: Effect of Hearing Rehabilitation Therapy

Jae Sang Han, MD\textsuperscript{1}; Jung Mee Park, MD\textsuperscript{2}; Yeonji Kim, MD\textsuperscript{1}; Jae-Hyun Seo, MD, PhD\textsuperscript{1}; Dong Kee Kim, MD, PhD\textsuperscript{1}; So Young Park, MD, PhD\textsuperscript{1}; Shi Nae Park, MD, PhD\textsuperscript{1}

\textsuperscript{1}Department of Otorhinolaryngology-Head and Neck Surgery, College of Medicine, The Catholic University of Korea, Seoul, Republic of Korea

\textsuperscript{2}Department of Otorhinolaryngology-Head and Neck Surgery, Gangneung Asan Hospital, College of Medicine University of Ulsan, Gangneung, Republic of Korea

Conflict of Interest Statement

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Corresponding author: Shi Nae Park, MD, PhD

Department of Otolaryngology Head & Neck Surgery, Seoul St. Mary’s Hospital, College of Medicine, The Catholic University of Korea, 222, Banpo-daero, Seocho-gu, Seoul, 06591, Republic of Korea

Tel: 82-2-2258-6215, Fax: 82-2-595-1354, Email: snparkmd@catholic.ac.kr
Contributions

Conceptualization: JMP, SYP, SNP. Data curation: JSH, JMP, YK. Formal analysis: JSH. Funding acquisition: SNP. Methodology: JSH, JMP, YK, SNP. Project administration: JSH, JMP, YK, SNP. Visualization: JSH. Writing–original draft: JSH, SNP. Writing–review & editing: JMP, YK, JHS, DKK, SYP, SNP.

ORCID ID

Jae Sang Han: 0000-0001-7728-1232
Jung Mee Park: 0000-0001-8589-4119
Yeonji Kim: 0000-0003-3127-5827
Jae-Hyun Seo: 0000-0002-8443-8581
Dong Kee Kim: 0000-0003-1125-3452
So Young Park: 0000-0003-3127-5827
Shi Nae Park: 0000-0002-7614-9413

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HIGHLIGHTS

- Effect of hearing rehabilitation therapy (HRT) program in hearing aid users was evaluated.

- The program consisted of 30-min training sessions by an expert and a daily self-HRT.

- Higher compliance rate; it suggests that short time/face-to-face HRT is effective.

- Consonant perception tests and questionnaires scores were significantly improved.
Effect of Hearing Rehabilitation Therapy Program in Hearing Aids Users: A Prospective Randomized Controlled Study

Abstract

Background: Despite sufficient hearing gains, many patients with hearing loss have difficulty using hearing aids due to poor word recognition ability. This study was performed to introduce our hearing rehabilitation therapy (HRT) program for hearing aid users and to evaluate its effect on hearing improvement.

Study Design: Prospective randomized case-control study.

Subjects and Methods: Thirty-seven participants with moderate to moderate-severe sensorineural hearing loss who had used bilateral hearing aids for more than three months with sufficient functional hearing gain were enrolled in this study. Nineteen participants were randomly assigned to the control group (CG) and 18 patients were assigned to participate in our HRT program once a week for eight consecutive weeks (hearing rehabilitation therapy group, HRTG). Their hearing results and questionnaire scores regarding hearing handicap and hearing aid outcomes were prospectively collected and compared between the two groups.

Results: After completing eight weeks of the HRT program, the HRTG showed significantly higher delta score of consonant-only and consonant-vowel sound perception compared to the CG (p<0.05). In addition, the HRTG had a significant improvement in hearing ability as measured by two questionnaires (p<0.05), while no differences were observed in the CG. However, word and sentence recognition test results did not show significant differences between the two groups.

Conclusion: Even after short-term HRT, patients had subjectively better hearing outcomes and improved phoneme perception ability; this provides scientific evidence regarding a possible positive role for HRT programs in hearing aid users. Further validation in a larger population with a long-term follow-up study is needed.

Keywords: hearing loss; hearing rehabilitation therapy; hearing aids
INTRODUCTION

Hearing loss is a major issue in healthcare. Around 466 million people worldwide were estimated to suffer from hearing loss in 2018, and the number has risen steeply as the elderly population grows [1]. Hearing deteriorates with age, and about 80 percent of hearing loss patients are elderly [2]. Hearing loss in the elderly causes limitations in daily activity and depression. Moreover, uncorrected hearing loss is related to cognitive impairment, which suggests that appropriate interventions for hearing loss in the elderly are essential [3].

Use of hearing aids (HAs) is a main approach for hearing rehabilitation in the elderly, and its effectiveness for health-related quality of life has been shown in a systemic review [4]. However, the prevalence of HA use in hearing loss patients was reported at only 17.4 to 37 percent, and about one-third of HAs are not used after fitting [5,6]. The main reason for not using HAs is the lack of significant improvement, which is mostly related to the sound being louder but still not being able to understand the words, especially in noisy environments [7]. This is because HAs can help with the ‘hearing’ process, which simply means perception of sound, but there is a limit in listening and comprehension, which is the main process of understanding sound [8]. To overcome this limitation, clinicians need to consider other additional rehabilitation therapeutic modalities, such as hearing rehabilitation therapy (HRT), for HA users [9].

Worldwide, several web-based hearing rehabilitation programs, such as Listening and Communication Enhancement (LACE) [10] and Customized Learning: Exercises for Aural Rehabilitation (clEAR) [11], have been commercialized. Studies on their clinical effectiveness and usefulness have been proposed; however, the lack of well-designed prospective studies showing scientific evidence for the effect of HRT makes it difficult prove that this is an effective therapeutic modality.
Moreover, clinical studies on hearing rehabilitation or auditory training in hearing aid users in Korea remain in the early stages. To our knowledge, most reports conducted by Korean-based auditory training were case reports and only one case-controlled study with a small number of enrolled subjects was reported [12].

The aim of this study is to introduce our HRT program and to evaluate its effect on hearing improvement in HA users in a prospective randomized clinical trial.

SUBJECTS AND METHODS

Ethical Considerations

This prospective study was approved by the Ethics Committee of Seoul St. Mary’s Hospital (KC18EESI0403) and followed the tenets of the Declaration of Helsinki. The patient records and information were anonymized and de-identified before analysis. All participants provided written informed consent prior to commencement of the study and voluntarily participated in this clinical trial.

Subjects

We included 40 participants with sensorineural hearing loss (SNHL) who had been wearing bilateral HAs and were recruited from the department of otorhinolaryngology-head and neck surgery at a tertiary referral center between November 2018 and January 2020. Study eligibility criteria specified adults aged more than 20 years with moderate to severe SNHL in both ears. Moderate to severe hearing loss was diagnosed when the average value of pure tone audiometry (PTA) measured at 500, 1000, 2000, and 4000 Hz was 41 to 80dB [13]. All patients had used bilateral HAs for more than three months with sufficient hearing gains. They were randomly divided into the hearing rehabilitation therapy group (HRTG) and the control group (CG) by random allocation.
cards using computer-generated random numbers. Two HRTG participants were excluded at their first visit because of low compliance, and 1 CG participant was dropped during the study period due to follow-up loss (‘no time to visit’). Consequently, the data from 18 HRTG participants and 19 CG participants were prospectively collected (Figure 1). HRTG participants participated in an 8-week-scheduled HRT program, while CG participants had no interventions. All participants completed assessments including hearing tests and questionnaires on the day of registration and at 4- and 8-week follow-up visits.

**Hearing Rehabilitation Therapy Program**

**Auditory Training Program Protocol**

Our 8 week - HRT program consists of two components: 1) professionals’ face-to-face interview and training sessions: 3 sessions of doctor’s interview and 8 sessions of audiologist’s 30-min face-to-face HRT and 2) daily homework for self-hearing rehabilitation. HRTG participants received our HRT program once a week for 8 consecutive weeks. During the first 4 weeks, consonant discrimination retraining was conducted, followed by retraining in consonant identification and understanding for the next five to eight weeks.

Consonant discrimination retraining consisted of three steps. The first step was to choose whether two sounds with the same consonants were the same or not; for example, if the sounds were M-Ah and M-Eu, the answer is ‘No.’ The second step was similar to the first step but was tested with three sounds with the same consonants. The third step was to listen to three words, two that were the same and one that was different, and to choose the word that was different.
Retraining in consonant identification and understanding was conducted in two steps. The first step was to listen to three words and tell what the other one was, and the second step was to listen to three words and write down what the other one was. All steps were performed under audio-visual conditions and were then carried out under audio-only conditions if the participants had done well in the previous step.

The sound level used in HRT was adjusted to the most comfortable level, and the 10 most frequently used Korean consonants (m, n, r, g, h, teh, j, s, and s*; from low-frequency to high-frequency consonants) were selected according to Korean National Institute of Special Education-Developmental Assessment of Speech Perception (KNISE-DASP) for training [14]. Low-frequency consonants were used first and retraining gradually moved to high-frequency consonants. If the participant chose more than 85% correct answers during HRT, they moved to the next level.

**Daily Self-Home Training Program**

A self-training handout was provided to the HRTG participants so that they could perform daily HRT at home. The handout consisted of three sessions: first session - words starting with one consonant; second session - words with the same consonant in the middle; and third session - words with a final consonant. Of the 10 consonants selected by KNISE-DASP, low- to high-frequency consonants were used in sequence. The participants were asked to read the words out loud to hear the differences, and a checklist to record the completion of their own training was provided to confirm their compliance of HRT. The average time for self-training as a homework was about 30 to 40 minutes per day, which was similar to face-to-face HRT session in the hospital.

The process of the HRT program is described in Figure 2.
Outcome Measures

All participants completed hearing tests and questionnaires at the 0-, 4-, and 8-week visits. Pure tone audiogram (PTA) without HAs and sound field threshold audiometry testing with HAs were conducted to exclude changes in hearing level and inappropriate function of HAs. Audiological outcomes were evaluated with word recognition score (WRS), Korean consonant perception test (KCPT) [15], and Korean speech perception in noise (KSPIN) test [16]. Subjective benefits were measured by two validated questionnaires: the Korean Version of the Hearing Handicap Inventory (K-HHIE) and the International Outcome Inventory for Hearing Aids (K-IOI-HA) [17,18].

Statistical Analysis

In order for statistical significance at 0.05 confidence level with 80% power, the sample size required for the two groups was estimated as 18 patients per each group. Allowing for a 10% dropout rate, 42 patients were estimated to be required in total. However, 40 patients finished the study protocol and were finally enrolled in this study, which were the sufficient patient number for statistical analysis.

Statistical analysis was conducted using SAS Version 9.4 (SAS Institute, Cary, NC). The Shapiro-Wilk test was used to examine the normality of the measured variables. Data was expressed as mean, standard deviation, and percentage. P values were calculated using the Chi-square test or Fisher's exact test for categorical variables, the Mann-Whitney test or t-test for two independent variables, the Wilcoxon rank sum test or t-test for continuous variables, and linear mixed-effects model for repeated measured variables. Differences were considered significant when the p-value was less than 0.05.
RESULTS

Clinical characteristics

We statistically analyzed data from a total of 38 participants, consisting of 37 participants who had completed the assessment and one CG participant who performed only the first evaluation. The ages ranged from 55 and 86 years, with a mean of 72.7 years, and the male to female ratio was 13:25. There was no statistically significant difference in age ($p=0.419$) or sex ratio ($p=0.428$) between the HRTG and CG groups. All participants used bilateral HAs which were either completely-in-the-canal (CIC) or receiver-in-the-canal (RIC) (CIC: 63 ears, RIC: 13 ears) type. The mean duration of HA use was 42.2±33.4 months, varying from 3 months to 120 months. No statistically significant differences were observed regarding HA type ($p=0.261$) or duration of HA use ($p=0.392$) between the two groups. The better-hearing ear as assessed by PTA average was the right ear in 23 patients and the left ear in 15 patients, without significant differences between the groups. The detailed data are shown in Table 1.

Audiologic Evaluations

Baseline Audiologic Tests

In the initial PTA results, there was no significant difference in average hearing threshold level between the two groups at all frequencies, regardless of unaided/aided conditions or better/worse ear ($p>0.05$, Figure 3A). The initial WRS also did not differ between the two groups ($p>0.05$, Figure 3B).
Therapeutic Effects of HRT program

Audiology Results

Data from one participant who was lost to follow-up after the first visit was excluded from assessment. There were no significant improvements in the WRS and KSPIN test results in either group (p>0.05). However, the KCPT results showed significant improvement in both conditions (consonants only, consonants plus vowel -a) regardless of HRT (p<0.001) (Table 2). Additionally, the delta scores (third visit score minus first visit score) of the KCPT results were compared to assess the difference in degree of improvement between the two groups. The delta values for consonants with the vowel ‘–eu’ were 8.83 ± 4.83 in the HRTG and 4.68 ± 4.60 in the CG, and the delta values of consonants with the vowel ‘–a’ were 6.39 ± 4.04 in the HRTG and 3.63 ± 3.84 in the CG. Significantly higher mean delta scores were observed in the HRTG regardless of test conditions (p<0.05) (Figure 4).

Questionnaire Results

K-IOI-HA scores were 25.6 ± 4.5 in the HRTG and 26.1 ± 4.2 in the CG at the first visit (p=0.701), 28.3 ± 4.2 in the HRTG and 27.3 ± 4.3 in the CG at the second visit (p=0.279), and 29.4 ± 4.3 in the HRTG and 27 ± 4.5 in the CG at the third visit (p=0.100). According to longitudinal data analysis, significant improvement was observed in the HRTG (p<0.001) but not in the CG (p=0.117).

K-HHIE scores showed similar results. The initial mean total score was 36.6 ± 28.1 in the HRTG and 33.5 ± 26.3 in the CG (p=0.770), 26.4 ± 26.6 in the HRTG and 29.6 ± 25.8 in the CG at the second visit (p=0.594), and 19.4 ± 20.8 in the HRTG and 28.2 ± 26.4 in the CG in the final visit (p=0.170). There was a significant change between initial and final visits in the HRTG (p<0.001) but not in the CG (p=0.174). The
emotional scores in the HRTG were 17.2 ± 14.8 at the first visit, 12.6 ± 14.1 at the second visit, and 8.2 ± 9.9 at the final visit, while the emotional scores in the CG were 15.7 ± 14.6 at the first visit, 13.6 ± 14 at the second visit, and 13.3 ± 14.5 at the final visit. The serial mean scores on the social/situational K-HHIE were 19.3 ± 13.9, 13.9 ± 13.4, and 11.2 ± 11.3 in the HRTG and 17.8 ± 12.4, 16.0 ± 12.3, and 14.9 ± 12.3 in the CG, respectively. Significant improvements in both emotional and social/situational K-HHIE values were observed only in the HRTG (p<0.001 in both scores) based on longitudinal data analysis (p-values for the CG: 0.228 in emotional scores and 0.151 in situational score). These questionnaire results are presented in Figure 5.

In addition, 12 out of 18 participants (66.67%) in the HRTG and 5 out of 19 participants (26.32%) in the CG showed a more than 36% decrease in their social/situational K-HHIE scores, which indicate significant changes of K-HHIE scores in both groups.[19] However, the differences of the changes between two groups was statistically significant (p=0.014).

DISCUSSION

Compliance of HRT

Compliance is an important factor for better outcomes in HRT, but one study reported that the compliance rate for a cohort of home-based HRT trainees was less than 30% [20]. Other previously conducted randomized controlled trials reported various compliance results. Hickson et al.[21] conducted a controlled study evaluating a group program of active communication education of 2 hours per week for 5 weeks, and only 82 of the 178 participants (46%) completed all the programs. Preminger and Ziegler[22] reported a 91% (31/34) completion rate of one hour per week of a group speech perception training program for a 6-week schedule, and Humes et al.[23] reported an
87% (13/15) completion rate for a 6-week scheduled at-home auditory training program. Table 3 summarizes the compliance results of other studies.

In our study, only two out of a total of 20 participants in HRTG had trouble completing our HR program; one was unable to implement the self-home training program due to illiteracy and one found it difficult to concentrate on the program itself. A total of 18 participants who were able to follow our HRT program completed the 8-week schedule resulting in a high compliance rate (90%).

No consensus has been established regarding the factors or methods for the better compliance in hearing rehabilitation therapy yet. However, our 30-minute face-to-face HRT sessions by an audiologist as well as three separate interviews and reinforcement by an ENT doctor during the 8-week program seem to increase the patients’ compliance, which differs from the protocols of other studies. It is assumed that reinforcing patients’ motivation by both a trainer (therapist) and a doctor in a face-to-face manner is the one of the important factors for the higher compliance during hearing rehabilitation therapy.

The short but intensive method in which our HRT program was conducted requiring the completion of daily self-home training checklists might be another reason why we have higher compliance compared to previously reported methods of HRT with longer sessions. A shorter training session time has been proposed to be more effective for auditory perceptual learning to increase compliance [20,24].

**Therapeutic Effectiveness of HRT**

WRS, KCPT, and KSPIN tests were conducted to evaluate audiologic outcomes in our study, but significant improvements were observed only in the KCPT results. There is controversy on whether audiological outcomes can be enhanced by HRT in HA users.
Sweetow and Sabes[25] reported improvement in quick speech in the noise test and
Stecker et al.[26] reported improvement in the nonsense syllable test after auditory
training. However, other studies reported opposing results and a meta-analysis
concluded that there was no significant audiologic improvements after auditory training
[9].

In this study, reasons why we did not observe significant improvement in WRS
and KSPIN test results include the possibility that our 8-week HRT period was too short
to show significant results or that our program did not include hearing training in a
noisy environment. Further studies with a longer training period and a training protocol
including hearing training in a noisy environment will be required to support these
hypotheses. In addition, KCPT scores in CG were also improved at 4 and 8 weeks of
follow-up even though the delta scores were smaller than HRTG. Repeated exposure to
the same test or the hearing rehabilitation effects caused by everyday hearing aid use in
CG might be the possible reason why we could observe the improvement of KCPT
scores in both groups.

**Subjective Satisfactions about HRT**

As that final goal of HRT in HA users is to improve communication skills in everyday
life, self-reported measures might be more appropriate than laboratory speech
recognition tests [27]. The HHIE is widely used as a self-assessment tool to quantify the
effect of hearing loss on the emotional and situational adjustment of elderly with high
reliability and validity[18]. Our study results showed a significant improvement in K-
HHIE score only in the HRTG, in which a higher percentage of participants had
significant improvement. The HHIE consists of two subsections; the social/situational
subsection is comprised of questions about social disruption due to hearing loss while
the emotional subsection is composed of questions to determine the emotional response
due to hearing impairment. Our findings showed significant decreases in scores of both
subsections after HRT. Although there are some differences in intervention methods,
previous studies using HHIE as a parameter reported improvements and our study
results support this. de Miranda et al.[28] reported a significant decrease in HHIE score
following formal auditory training of elderly HA users, and Lundberg et al. [29]
reported improvements in HHIE score and depression scale after an educational
program with telephone consultations.

The IOI-HA questionnaire has been developed to quantify the satisfaction of HA
users and consists of a total of seven questions on daily use, benefit, residual activity,
satisfaction, residual participation restrictions, impact on others, and quality of life [30].
In other previous studies, no significant improvement in IOI-HA scores was observed
after hearing aid use [29], and it has been suggested that the IOI-HA is not sensitive
enough to detect the benefits of HAs [31]. Humes et al.[23] reported no significant
improvements in three questionnaires (profile of hearing aid performance, PHAP;
hearing aid satisfaction survey, HASS; and HHIE) after an at-home auditory training
program for HA users.

However, our study and previous studies have reported that HRT or auditory
training programs improve subjective satisfaction with HAs, which might be related to
the different methods applied. Humes et al. used a computer-based training process,
while studies reporting improvement in subjective satisfaction were based on either
face-to-face or telephone training [28,29]. The results of various studies are summarized
in Table 3.

It can be assumed that hearing training with personal communication rather than
a solely computer-based process can be more effective for HA users. The good
compliance and therapeutic effect of our HRT program as evidenced by a prospective randomized case-control study reveals the value of HRT programs in HA users. The limitations of this study are a relatively short duration of our 8-week HRT program and the small numbered subject-control experiments, which might be not enough to show the significant improvements in WRS and KSPIN tests.

CONCLUSION

This prospective randomized controlled study was conducted to evaluate the effectiveness of our HRT program consisting of specialists’ face-to-face instruction with 30 min HRT sessions and daily self-administered HRT for HA users. Our HRT program showed significant improvements in the consonant perception test and self-reporting measures (K-HHIE and K-IOI-HA) and a higher compliance rate than other programs. This HRT program strategy could prove beneficial to many HA users.

REFERENCES


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<th>HRTG (N=18)</th>
<th>CG (N=20)</th>
<th>P-value</th>
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<tr>
<td>Age (years ± standard deviation)</td>
<td>73.9 ± 8.8</td>
<td>71.6 ± 8.8</td>
<td>0.419†</td>
</tr>
<tr>
<td>Sex (male: female)</td>
<td>5:13</td>
<td>8:12</td>
<td>0.428++</td>
</tr>
<tr>
<td>Hearing aid type (CIC: RIC, ears)</td>
<td>28 : 8</td>
<td>35 : 5</td>
<td>0.261++</td>
</tr>
<tr>
<td>Hearing aid usage (months)</td>
<td>45.8 ± 33.2</td>
<td>39.0 ± 34.1</td>
<td>0.463++</td>
</tr>
<tr>
<td>Better hearing side (right: left)</td>
<td>12 : 6</td>
<td>11 : 9</td>
<td>0.392†</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± standard deviation. HRTG, hearing rehabilitation therapy group; CG, control group; CIC, complete in the canal; RIC, receiver in the canal.
†Mann-Whitney test, ††Fisher’s exact test.
Table 2. Evaluation of therapeutic effectiveness of the hearing rehabilitation therapy program

### A. Word Recognition Score

<table>
<thead>
<tr>
<th></th>
<th>1&lt;sup&gt;st&lt;/sup&gt; visit</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; visit</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; visit</th>
<th>P-value&lt;sup&gt;†&lt;/sup&gt;</th>
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<tr>
<td>HRTG</td>
<td>73.8 ± 8.1</td>
<td>74.4 ± 7.9</td>
<td>74.9 ± 8.3</td>
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<tr>
<td>CG</td>
<td>73.5 ± 17.8</td>
<td>74.0 ± 19.3</td>
<td>74.1 ± 20.1</td>
<td>0.591</td>
</tr>
<tr>
<td>P-value</td>
<td>0.310&lt;sup&gt;††&lt;/sup&gt;</td>
<td>0.344&lt;sup&gt;††&lt;/sup&gt;</td>
<td>0.454&lt;sup&gt;††&lt;/sup&gt;</td>
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### B. Korean Consonant Perception Test

<table>
<thead>
<tr>
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<th>1&lt;sup&gt;st&lt;/sup&gt; visit</th>
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<th>3&lt;sup&gt;rd&lt;/sup&gt; visit</th>
<th>P-value&lt;sup&gt;†&lt;/sup&gt;</th>
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<tr>
<td>Consonant only</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>HRTG</td>
<td>12.6 ± 7.3</td>
<td>17.7 ± 7.0</td>
<td>21.4 ± 6.4</td>
<td>&lt;0.001</td>
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<tr>
<td>CG</td>
<td>12.3 ± 8.2</td>
<td>15.3 ± 7.6</td>
<td>17.6 ± 7.1</td>
<td>&lt;0.001</td>
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<tr>
<td>P-value</td>
<td>0.920&lt;sup&gt;†††&lt;/sup&gt;</td>
<td>0.336&lt;sup&gt;†††&lt;/sup&gt;</td>
<td>0.100&lt;sup&gt;‡‡&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Consonant + Vowel -A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRTG</td>
<td>14.9 ± 6.5</td>
<td>18.5 ± 6.1</td>
<td>21.3 ± 6.5</td>
<td>&lt;0.001</td>
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<tr>
<td>CG</td>
<td>14.1 ± 6.9</td>
<td>15.5 ± 7.3</td>
<td>17.8 ± 7.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>P-value</td>
<td>0.720&lt;sup&gt;†††&lt;/sup&gt;</td>
<td>0.182&lt;sup&gt;†††&lt;/sup&gt;</td>
<td>0.203&lt;sup&gt;‡‡&lt;/sup&gt;</td>
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### C. Korean Speech Perception in Noise Test

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<tr>
<td>HRTG</td>
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<td>0.306&lt;sup&gt;‡‡&lt;/sup&gt;</td>
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<tr>
<td>SNR 0</td>
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<tr>
<td>HRTG</td>
<td>8.1 ± 15.1</td>
<td>11.2 ± 17.0</td>
<td>10.6 ± 16.2</td>
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</tbody>
</table>

Values are represented as mean ± standard deviation. † P values are calculated by linear mixed-effects model. ‡‡ P values are calculated using the Wilcoxon rank sum test or t-test for continuous variables. HRTG, hearing rehabilitation therapy group; CG, control group; SNR, Signal-to-noise ratio.
Table 3. Summary of randomized controlled trials for auditory training in hearing aid users.

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Placebo</th>
<th>Compliance (Completed/Enrolled)</th>
<th>Age</th>
<th>Training Method</th>
<th>Intervention</th>
<th>Duration</th>
<th>Measures</th>
<th>Positive Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Han et al.</td>
<td>Bilateral HA users (at least 3 months)</td>
<td>No</td>
<td>18/18 (100%)</td>
<td>55-86</td>
<td>Individual</td>
<td>Consonant training (perception, discrimination, comprehension)</td>
<td>4 hours over 8-week period</td>
<td>WRS, CPT, SPIN, HHIE, IOI-HA</td>
<td>CPT, HHIE, IOI-HA</td>
</tr>
<tr>
<td>Hickson et al. [20]</td>
<td>Some HA users (approximately half)</td>
<td>Yes</td>
<td>82/178 (46%)</td>
<td>53-94</td>
<td>Group</td>
<td>Active communication education</td>
<td>10 hours over 5-week period</td>
<td>HHQ, SAC, QDS, Ryff, SF-36 PCS, COSI, IOI-HA</td>
<td>HHQ, SAC, QDS, Ryff, COSI, IOI-AI</td>
</tr>
<tr>
<td>Preminger and Ziegler</td>
<td>HA users (at least 3 months)</td>
<td>No</td>
<td>31/34 (91%)</td>
<td>55-75</td>
<td>Group</td>
<td>Speech perception training</td>
<td>5-6 hours over 6-week period</td>
<td>Analytic and synthetic speech perception, HHIE, WHODAS II</td>
<td>HHIE</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Study</th>
<th>HA users</th>
<th>Yes (audiobooks)</th>
<th>12/15 (80%)</th>
<th>Tablet computer-based</th>
<th>At-home auditory training program</th>
<th>5-week period</th>
<th>CST, CID, PHAP, HHIE, and HASS, ANL</th>
<th>CID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humes et al. [22]</td>
<td>HA users</td>
<td>Yes</td>
<td>54-80</td>
<td>Tablet</td>
<td>At-home auditory</td>
<td>5-week</td>
<td>CST, CID, PHAP, HHIE, and HASS, ANL</td>
<td>CID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(audiobooks)</td>
<td></td>
<td>computer-based</td>
<td>training program</td>
<td>period</td>
<td></td>
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</tr>
<tr>
<td>Stecker et al. [25]</td>
<td>HA users</td>
<td>No</td>
<td>31†</td>
<td>Personal</td>
<td>Perceptual training</td>
<td>8-week</td>
<td>NST</td>
<td>NST</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>computer-based</td>
<td></td>
<td>training period</td>
<td></td>
<td></td>
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<tr>
<td>Sweetow and Sabes [24]</td>
<td>HA users</td>
<td>No (cross-over)</td>
<td>49/65</td>
<td>Web-based</td>
<td>LACE™</td>
<td>4-week</td>
<td>QuickSIN, HINT, HHIE, CSOA, QuickSIN, HHIE, CSOA</td>
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<tr>
<td></td>
<td>(56)</td>
<td></td>
<td>28-85</td>
<td></td>
<td></td>
<td>period</td>
<td></td>
<td></td>
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<td></td>
<td>Non-HA</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>users (9)</td>
<td></td>
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<tr>
<td>J Yu et al. [12]</td>
<td>HA users</td>
<td>Yes (traditional training)</td>
<td>10†</td>
<td>Mobile-based</td>
<td>Consonant training (perception, discrimination, comprehension)</td>
<td>16 hours over 4-week period</td>
<td>Speech recognition scores</td>
<td>Consonant and sentence tests</td>
</tr>
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</tbody>
</table>

HA, hearing aid; WRS, Word Recognition Score; CPT, consonant perception test; SPIN, speech perception in noise; HHIE, Hearing Handicap Inventory for the Elderly; IOI-HA, International Outcome Inventory for Hearing Aids; HHQ, Hearing Handicap Questionnaire; SAC, Self-Assessment of Communication; QDS, Quantified Denver Scale of Communicative Function; Ryff, Ryff Psychological Well-Being Scale; SF-36, Short-Form 36; COSI, Client Oriented Scale of Improvement; WHODAS II, World Health Organization Disability Assessment Schedule II;
CST, Connected Speech test; CID, Central Institute for the Deaf sentence materials; PHAP, profile of hearing aid performance; HASS, hearing aid satisfaction survey; ANL, acceptable noise level, LACE, Listening and Communication Enhancement; QuickSIN, Quick Speech In Noise; HINT, Hearing in Noise Test; CSOA, Communication Scale for Older Adults; NST, Nonsense Syllable Test. †No information on participants who completed the training.
Figure captions

Figure 1. Flow diagram for the hearing rehabilitation therapy clinical trial.

Figure 2. A scheme of hearing rehabilitation training (HRT) protocol. The HRT program consists of face-to-face training and self-home training with three times interview with an ENT doctor. A 30-minute face-to-face training was conducted once a week for eight weeks, with the first 4-week of constant discrimination retraining and 5-8 weeks of identification and understanding training. At the same time, self-home training was taught to patients to do it every day at home. In the training process, the ten most commonly used Korean consonants were used for training, starting with low frequency consonants and gradually progressing to high frequency consonants. A doctor’s role during our HRT program is three times of interview with the patient for HRT prescription, reinforcement as well as final motivation for self-HRT. HRT, hearing rehabilitation training.

Figure 3. Baseline results of pure tone audiometry (A) and word recognition score (B) show no significant differences between the auditory training group and the control group (p>0.05, Mann-Whitney test or t-test). Error bars indicate standard deviation. PTA, pure tone audiometry; HRTG, hearing rehabilitation therapy group; CG, control group.
Figure 4. Delta scores of the Korean consonant perception tests. Significantly higher mean delta scores were observed in the HRTG under both consonant only and consonant+vowel conditions (*$p<0.05$, Mann-Whitney test). A box and whisker plot shows summary of a set of data: Maximum, 75 percentile, median, 25 percentile and minimum. HRTG, hearing rehabilitation therapy group; CG, control group.

Figure 5. Changes in hearing questionnaire scores. The K-IOI-HA score gradually increased in the HRTG, but no significant change was observed in the CG, indicating that the HRTG group had higher satisfaction than the CG with hearing aid use. Additionally, social/situational, emotional, and total scores on the K-HHIE questionnaire were significantly decreased in the HRTG, while no changes were observed in the CG, indicating that the level of discomfort regarding hearing loss has significantly decreased after HRT. K-IOI-HA, Korean version of International Outcome Inventory for Hearing Aids; K-HHIE, Korean version of Hearing Handicap Inventory; HRTG, hearing rehabilitation therapy group; CG, control group. (***$p<0.001$, linear mixed-effects model)
Total participants (n=40)

Randomized

Hearing rehabilitation therapy group (n=20)
- Completed allocated training (n=18)
- Dropped during training (n=2, because of low compliance)
- Follow-up loss (n=0)

Control group (n=20)
- Completed allocated training (n=19)
- Dropped during training (n=0)
- Follow-up loss (n=1)

Analyzed (n=18)

Analyzed (n=19)
**Face-to-face HRT in Hospital**
- About 30-min session
- Once a week

**Daily Self-Home Training Program**
- Read the words loud themselves
- Check-up list was provided

**Doctor’s Role**
- Interview
- HRT prescription

**1-4 weeks**
Consonant Discrimination Retraining (AV→AO)
- **Step 1**
  - Discriminate two sounds with same consonants.
- **Step 2**
  - Discriminate three sounds with same consonants.
- **Step 3**
  - Discriminate three words with same consonants.

**5-8 weeks**
Consonant Identification and Understanding Retraining (AV→AO)
- **Step 1**
  - Listen to three words and tell what the other one was.
- **Step 2**
  - Listen to three words and write down what the other one was.

**Consonants**
m, n, r, g, b, h, tɕh, j, s and s* from low frequency to high frequency consonants