Critical Review: What is the Efficacy of Prescribing Frequency Lowering Devices for Adult Patients?

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This critical review seeks to determine the efficacy of prescribing frequency lowering devices for adults patients. This review specifically examines the use of nonlinear frequency compression (NFC). The studies included in this review are single group pre-posttest design, single subject design and a systematic review. The studies examined suggest inconclusive results because of the methodological limitations found in most of the studies. Future considerations and clinical recommendations are examined and discussed.

Introduction

Frequency lowering, specifically, nonlinear frequency compression (NFC) is a technology that reduces the bandwidth of the outgoing signal by a specific ratio (Glista, Scollie, Begatto, Seewald, Parsa and Johnson, 2009). This is necessary due to the inability for hearing instruments without this technology to amplify high frequency sounds and also because of dead regions that may exist in patient's cochlea (Simpson, 2009, Baer, Moore, and Kluk, 2002).

Many hearing instrument manufacturers have different frequency lowering techniques. Phonakis an exampled of a hearing instrument manufacturer that uses NFC to lower the higher frequencies that may not be audible to hearing instrument users. This allows the person programming the hearing instrument to adjust the compression of some frequencies, specifically, the higher ones, where the lower frequencies remain the same (Simpson, 2009). The cut-off frequency is the point at which anything below is untouched and anything above is compressed into a smaller bandwidth (Simpson, 2009).

Hearing instruments have a limited bandwidth for providing gain and usually roll-off past 6000 Hz. High frequency sounds are important for plural identification, possession, third-person present tense and sounds with less intensity (Simpson, 2009). These sounds are much higher in frequency than the average roll-off frequency, with some women and other children's voices being 9000 Hz. for these high frequency sounds (Wolfe et al. 2009). This is especially important for children who are acquiring language and thus much research has been focused on the benefits of nonlinear frequency compression in children.

Frequency lowering techniques have recently been studied vigorously by a handful of researchers with most research showing children almost always benefit from this technology (Glista et al., 2009, Simpson, 2009, Scollie et al., 2007). The ability to hear these sounds are important for adults as well in order to improve the ease of listening because one does not need to fill in the gaps of speech because all sounds are present (Wolfe, et al. 2009).

There is some question whether this technology is appropriate for adult fittings, in particular, whether adults can adapt to the changes in sound quality produced by hearing instruments with nonlinear frequency compression (Glista et al., 2009, Simpson et al. 2006). The importance of determining the ability of adult patients to acclimatize to the sound of frequency lowering hearing instruments is vital to ensure that the prescription is useful, especially considering some of the limitations of hearing instruments previous stated. The novelty of this technology means that there is limited research on the efficacy of prescribing this to patients and even less research on adult patients. The review of this literature will provide clinicians with a better understanding of the efficacy of adult patients using nonlinear frequency compression.

Objectives

The primary objective of this paper is to critically examine the efficacy of prescribing frequency lowering technology to adult patients. The secondary objective is to provide recommendations for clinical practice and future research.

Methods

Search Strategy

Computerized databases were used to search the topic of interest including: Medline, PsychINFO, PubMed and Google Scholars. The keywords used for this search were:

[(frequency lowering) and (adult)]
[(non-linear frequency compression) and (adult)]
[(frequency transposition) and (adult)]

The search was limited to articles written in English and human subjects.

Selection Criteria

The studies included in this critical review investigated the use of frequency lowering technology with adult participants. No limits were set on the degree or type of hearing loss. Also, any type of frequency lowering technology was acceptable in the selection. There were also no limits set on the gender, race or socioeconomic status of the participant. Participants of the age of at least 18 were considered an adult for this review criterion.

Data Collection

The result of this literature search produced five articles consistent with the search criteria previously stated. Four of the articles were single group pre-post test design, with one being a single subject design. The final article was a systematic review of current literature. Only peer-reviewed articles were used in the data collection despite some promising research in process.

Results

Single group pre-posttest design and single subject design: Glista, Scollie, Bagatto, Seewald, Parsa and Johnson (2009) compared NFC with conventional processing in both adults and children. These researchers evaluated both laboratory and real-world outcomes of speech sound detection, speech recognition, and self-reported preference measures. There were 13 adult participants and eleven child participants recruited for this study. Real ear to coupler difference's were obtained for all participants ensuring the hearing instrument fitting was tailored to each participants ear size relative to the coupler. This ensures better target estimations when programming the hearing instruments.

Glista et al. (2009) used a modified withdrawal design with single and double-blind outcome measures. First, subjects were given the hearing instruments with conventional programming and given an outcome test battery. NFC was then enabled and participants were familiarized with that and given an outcome test battery. Later, NFC was optional and patients could switch programs on his/her hearing instrument to whatever program he/she preferred. Both the participants and the experimenters were unaware of which program was the treatment option (NFC) and which was the control (conventional processing);. The other aspect of the double blinding was during the computer administered speech testing done; the participants were unaware of what processor was enabled. Four objective tests were administered, aided speech sound detection, consonant recognition, plural recognition and vowel recognition.

This study was well formulated and the design of the study does address the research question. The methods were valid and participant eligibility criteria were specified. Randomization was employed and the study was double blinded, ensuring more reliable findings. A repeated measures ANOVA was used; which is a valid statistical measurement for this study because it is used for within group factors and in this case there was only one group. Confidence intervals were given.

The results of this article indicated that speech scores were higher in most tests, aside from vowel recognition; which did not change significantly. No change in the vowel recognition was a good result, as a change was not expected to be observed. Five out of the 12 adults had a statistically significant improvement of recognition of /s/ and /sh/ sound detection threshold. Participants with a greater amount of high frequency loss had more benefit from NFC. More adults did not prefer NFC and researchers suggested that perhaps adults need a longer acclimatization period to adjust to the NFC settings. Children appeared to derive more benefit and preference of the NFC technology. The methodology and statistical treatment of data was appropriate for this research. Although this study was well-formulated in both methodology and statistical treatment of data, the results are suggestive that adults may not be able to acclimatize to NFC and children derive more benefit from this technology. This is of compelling importance to the prescription of NFC for adult patients because it appears as though some adults can benefit from this new technology and others cannot.

Single group pre-post test design: Bonert, Nyffeler and Keilmann (2010) evaluated NFC in noise in comparison to conventional processing strategies. These researchers used both a speech test of understanding and questionnaires to evaluate the performance of NFC. The researchers used TDH headphones to evaluate hearing thresholds but did not specify which frequencies were tested and the type of sound booth used. No RECD's were obtained and therefore the targets used to program the hearing instrument were not tailored to the size of the participants ear canal relative to the coupler. There were 14 participants used in this study but 3 discontinued their participation at some point. This sample size is quite small but consistent with most studies of communication sciences. There was also no control group, however, this is also consistent with other studies of this nature.

Researchers used the Oldenburger Sentence test, comprised of 40 lists with 30 nonsense sentences composed of five real words that were divided into three blocks of ten sentences each. The participants were seated in the middle of a circle of loudspeakers and

background noise was played along with speech material, both at 65 dB. The test was done with the participants own hearing instrument and the experimental device (Phonak Naida BTE). The hearing instruments were programmed to have all noise reduction algorithms deactivated to examine only the NFC technology. The time for acclimatization was not given and this testing methodology was quite vague. The researchers did not indicate the validity of this test or whether this test had been specifically created for this research project.

The questionnaires consisted of two different lists of questions, where one was used directly after the initial fitting of the device evaluating the overall impression of the NFC. The second questionnaire was based on real-life application and was given in follow-up sessions. These questions were based on sound quality, loudness and usefulness in noise. The participants were asked to wear the device daily. There were four follow-up sessions where again the speech in noise test was done and the second questionnaire was completed. The researchers did not indicate if the participants were to switch between NFC and their conventional hearing instruments or if only NFC was used throughout the duration of the research.
There was no statistical analysis done on the speech testing results and it appeared as though the researchers focused more on the results and statistical analysis of the questionnaires. A t-test design (two-tailed) was performed with a $p<0.05$ for the questionnaires. This is a valid statistical analysis for a single group pre-posttest design study.
For seven of the eleven subjects, the NFC algorithm provided superior satisfaction based on the questionnaires given. In comparison to conventional hearing instruments, the participants speech in noise understanding was better with the NFC technology. Four out of the eleven subjects showed a decrease in performance on the speech intellibility task, two of the participants showed a small increase in performance and the rest showed improvement. This improvement was indicated to be non-significant using independent Student's t tests (two tailed) with statistical significance set at $p< 0.05$; which is appropriate for Single group pre-post test design. After periods of two and four month acclimatization, the mean value of satisfied users increased significantly. These results suggest that these adult participants may need a period of acclimatization to be satisfied with the performance of the NFC. This satisfaction was significantly different from conventional hearing instruments after the two and four month acclimatization periods in both noise and quiet situations.

This research suggests that adults need at least a two month acclimatization period to report satisfaction from the NFC algorithm but the flaws in the methodology and statistical analyses clearly degrades the validity of the research. The level of evidence is suggestive for both validity and importance in regards to the research question being examined in this review due to the previous stated explanations.

Simpson, Hersbach and McDermott (2005) examined NFC in comparison to conventional hearing instrument algorithms. The researchers studied the participants ability to recognize monosyllabic words with both algorithms. The subjects were experienced hearing aid users with moderate-to-severe sloping sensorineural hearing loss. The participants' hearing thresholds were measured with TDH headphones instead of insert earphones and the type of sound booth was not indicated. BTE power instruments were used, specifically, the Phonak Supero 412. This device is older technology where a body worn processor is used to provide the nonlinear frequency compression. Based on the date of publication, it is understandable that this type of processor was used but is now considered older technology and this information alone impacts the validity of the imminent results. The researchers did not verify the fittings and only used manufacturers settings. Participants were fitted with the conventional device several months before the study commenced; which allows the participants a time period to acclimatize to the same hearing instruments across the group. The researchers indicated how the cut-off frequency and preferred volume was determined; both staying the same for the duration of the study.

Each participant wore the experimental device home and used it for four to six weeks. The participants were then assessed with monosyllabic word recognition tests. Next, the participants wore the conventional aids and were re-tested after another four to six week trial period. The researchers did not indicate if the participants were blinded to the type of program or if the programmers of the hearing instruments were blinded as well. This may have influenced the validity of the study due to some bias' of the participants and the researchers.

The results of the study indicated that there was a statistically significant improvement for the NFC algorithm in comparison to the conventional hearing instruments for phoneme, consonant, fricative and vowel scores. Eight of the 17 subjects showed a significant score increase while one participant showed a significant decrease in scores. The remainder of the participants showed no increase or decrease. The researchers used the Holm-Sidak test to statistically analyze the data and a two-factor analysis of variance;

both are valid for a single group pre-posttest design. The statistical treatment of data was appropriate for this design.

This particular study is suggestive that adults could benefit from the use of NFC with a short acclimatization period. Despite some methodological limitations, the validity of the methods was rated as suggestive.
The methodological limitations do decrease the validity of the research; especially considering the dated technology used, but does support the prescription of NFC in adult hearing instrument users.

Simpson, Hersbach and McDermott (2006) reevaluated their previous results with this consecutive study with opposite results. The researchers used the same NFC scheme as in their previous study and tested speech in quiet, speech in noise and used questionnaires for participants to subjectively evaluate the performance of the NFC processor. The researchers suggested in the prior study that this type of processor might adversely effect music. Secondly, the cut-off frequencies are based on the participants' subjective ear. In the previous study, steeply sloping hearing losses were not included which is why the researchers sought to examine the use of NFC with steeply sloping hearing losses.

Only seven participants were used in this study, all of which had steeply sloping audiograms based on audiometric testing done with TDH headphones. This is again, a small amount of participants, leaving much of the results to chance and generalization may be limited. The subjects were not tested for cochlear dead regions. The same hearing instruments and body-worn processors were used in this research; which again, is dated technology. The hearing instruments were fitted with manufacturers software without electroacoustic verification.

Open-set monosyllabic words, closed-set medial consonants in quiet, and open-set sentences were presented with competing noise. Several different speech-testing methods were used and after testing there was a subjective assessment performed using "The Abbreviated Profile of Hearing Aid Benefit" questionnaire (Cox and Alexander, 1995). The same methodological limitations found in the previous study are repeated here in this study, which could adversely degrade the quality and validity of the results of the study.

The results showed that there were minimal improvements with the NFC hearing instruments in comparison to the conventional hearing instruments. There were no significant differences in group mean scores between NFC and conventional hearing instruments. Subjective testing showed that only one of the participants preferred the NFC scheme. The time period given for acclimatization was limited and this should also be taken into consideration when examining this research.

Clinicians should be weary of prescription or lack thereof of NFC based on this research because of the dated technology alone. There may or may not be a change in the results with the advancement in technology since this publication. This research is given a suggestive level of evidence indicating that NFC cannot be used for adults with steeply sloping audiograms.

Systematic Review: Simpson (2009) provides a systematic review of the current literature on frequency lowering hearing devices. The author sought to examine the current literature on all frequency lowering research studies to come to a conclusion about the prescription NFC and other frequency lowering schemes. The author also had some questions of candidacy and future clinical directions.

The author first defined the terms used in the review in a table format. Also, another table showed the research in chronological order indicating the type of processing device, number of participants, the type of hearing loss, the outcome measure, the training and the results. The results showed that with time the frequency lowering devices appear to improve showing that participants showed significant increases in scores. This table is first listed for studies that included adults and then studies including children. The tables allow for comparison across studies and make it easier to interpret the data. The author did not include the research strategy used to locate and select studies.

This review did not go through each paper separately, but rather separated the research based on the type of frequency lowering device. For the purpose of this paper, only the NFC section was examined in depth. Simpson's (2009) review was based on some older literature and therefore did not include some of the research listed in this review. This may degrade the validity of the paper considering the systematic review is only as good as the studies included. The author did critically examine the methodology of each study but did not investigate the statistical treatment of data as thoroughly.

The author suggested areas of future research being in the candidacy criteria and auditory training. Another area of future research was suggested to be NFC use with milder losses.

This author found that the past research was compelling, where it showed disappointing results for NFC, but current literature suggests some success with frequency lowering techniques overall. The summary and conclusions given by the author was that this NFC technology is beginning to show success but candidacy for this technology is not yet determined. Also, that auditory training to encourage acclimatization may be necessary.

There was no statistical treatment of data because of the nature of a systematic review, which is appropriate. Simpson's (2009) review suggests that the evidence is suggestive in validity and importance and more research should be done to determine if adults can benefit from this technology. This level of evidence is given because of the limitations of the methodology.

Discussion/Conclusion

Three of the five studies examined in this review suggested that the use of NFC with adults after an acclimatization period is appropriate. The remaining two papers, including the literature review, proposed that clinicians be cautious in the prescription of NFC to adults. One of the two studies suggesting that NFC may be inappropriate for adults had dated technology and a limited period for acclimatization and therefore cannot be completely reliable for recommendation of use of NFC in adults. Three of the five papers also had methodological issues that contribute to the suggestive rating given to every reviewed study (ie. No electroacoustic verification stated). For these reasons, NFC should be used on an individual basis.

The general trend seen in these studies is that there is improved speech perception in quiet and in noise, with some studies suggesting patient preference to NFC technology. The suggested preference seen from the patients is generally observed after a period of acclimatization.

Future research should examine the acclimatization period needed for adults to adjust to NFC. It would be beneficial for future studies to observe this in different degrees and configuration of hearing loss to see if there is any variation based on those variables. Also, methodological issues should be addressed in order to provide reliable results; including electroacoustic verification and up-to-date technology.

Clinical Implications

At this time, the advantages and disadvantages of NFC should be carefully examined for each patient because of the heterogeneity of the population. Also, if NFC is used for the adult population, clinicians should consider an acclimatization period based on the current literature. More research should be done in order to succinctly state whether NFC should be used or not with adult patients. The current literature is inconclusive as to whether NFC should be used with all adult patients, most likely due to the methodological problems. This current review promotes the use of NFC with a period given for acclimatization.

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