

Health Effects of Cochlear Implants



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Abstract

Aim To investigate whether people on a waiting list for cochlear implantation are more likely than those who have cochlear implants to suffer from illnesses which are potentially mediated by stress. **Method** A questionnaire, designed to assess the presence, persistence, and medication use associated with stress-related illnesses, was administered to two groups: those on a waiting list for cochlear implantation and adult users of cochlear implants. **Results** Those on the cochlear implant waiting list had significantly poorer health as indicated by: a greater number of conditions experienced in the past year, longer illness length when affected by a condition, medication use for a greater number of conditions, and poorer mental health. **Conclusion** There are lengthy waiting lists for adult cochlear implantation. The need to wait and the lack of a known date for surgery, in combination with having a profound hearing loss is likely to result in chronic stress. Chronic stress may increase the risk of physical and mental illness via physiological systems which mediate response to environmental threats. Cochlear implantation may alleviate chronic stress in people on the waiting list, and these findings support the hypothesis that this influences physical health.

1. INTRODUCTION

In New Zealand, access to cochlear implantation for adults is limited.¹ Adults must go on a waiting list with no advised date of surgery. Many remain on that waiting list for over a year, whilst knowing that an operation would likely provide them with many benefits: the mean time on the waiting list is around four years.

Position on the waiting list is subject to change because if new people are admitted to the list, they may be placed higher than existing applicants: position is based primarily on need as assessed by hearing disability. Waiting for medical intervention has been shown to increase stress² and reduce quality of life.²

Thus, people on the cochlear implant waiting list are in a position that may be considered stressful. In addition to the stress of waiting, the effects of acquired profound hearing loss are also likely to be stressful.

Social isolation,³ tinnitus,⁴ grief,⁵ and embarrassment⁶ can all be consequences of hearing loss and may all result in stress. Further to this, a reduction in social support due to deterioration of interpersonal relationships may also diminish one's capacity to cope with stress.⁷

Stress will lead to negative emotions and physiological arousal (Figure 1). This arousal, mediated by individual factors such as stress reactivity and recovery, and the effects of stress-related health behaviours, will lead to increased risk of physical and mental illness.

The development of a particular illness is affected by genetic predispositions, vulnerabilities, and previous illnesses or injury. Stress increases the risk of developing illnesses and

can aggravate current illnesses:⁸ it has been linked to diabetes, asthma, arthritis, and depression, among others.⁹

That stress affects people with hearing loss is supported by findings of reduced health-related quality of life,¹⁰ increased depression,¹¹ increased anxiety,¹¹ and poorer physical health¹⁰ in this group.

After cochlear implantation, an alleviation of stress may be expected. Cochlear implants (CIs) have been associated with better health-related quality of life¹² and reduced symptoms of mental illness.¹³ However, no published findings indicate whether the improvement seen with mental health extends to physical health.

The aim of this study was to investigate the health (physical and mental) of CI recipients and compare it to that of those on the CI waiting list.

2. METHOD

Participants

Two groups were compared: those on the Northern Cochlear Implant Trust (NCIT) waiting list for cochlear implantation and those who have received CIs through the NCIT or who are receiving follow-up care through the NCIT. A questionnaire was sent to all these individuals with approval from the Ethics committee of the University of Auckland (Ref no. 2010/199).

Candidacy for a CI depends upon having a bilateral severe to profound sensorineural hearing loss for their better ear and where hearing aids provide limited or no useful benefit. There is no maximum age for referral, and patients with additional needs are not excluded. Adults have normally acquired hearing

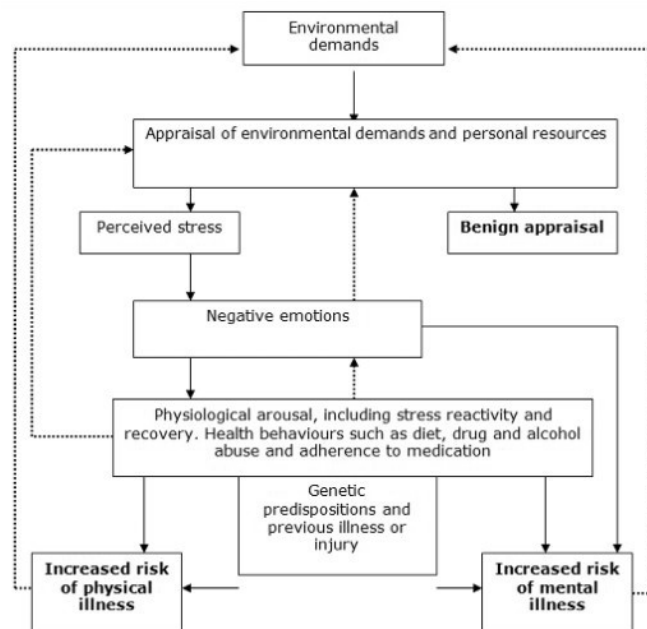


Figure 1. The development of psychophysiological illnesses. Solid lines indicate the processes through which illnesses develop due to stress and the dotted lines show how outcomes may feed back into this process and contribute to the burden of stress. Adapted from Cohen, Kessler and Gordon.⁸

loss post-lingually. In addition, the adults must be fit and well enough to undergo an operation. Of the 64 people on the waiting list, 44 (69%) responded.

The cochlear implant group consisted of adults who had received their implants at least 12-months ago, and were currently using, a cochlear implant through the NCIT, as well as those who had been implanted and funded by another provider (Accident Compensation Corporation (ACC) or private). Questionnaires were sent to 199 people for this group, and 119 (60%) responded.

Instruments

A questionnaire was created to investigate the presence and frequency of potentially stress-related, physical illnesses (Table 2): participants were asked to indicate how many days they suffered from symptoms of each condition in the previous year, thus creating variables that ranged from zero to 365; whether medication was used for each condition in the past year was also indicated. The 21-item Depression, Anxiety, and Stress Scale (DASS-21)¹⁴ was used to assess mental health.

This questionnaire which has three scales: Anxiety, Depression, and Stress, and can also be used, as we have, to provide a total mental-health score.

Questions about demographics, general health perception (Question 1 from the Short Form health questionnaire (SF-36)¹⁵), frequency of physician visits and sick days, and self-rated dissatisfaction with hearing (10-point scale; Figure 5) were also included. Furthermore, the following factors which may be associated with the relationship between stress and health were investigated: smoking,¹⁶ binge alcohol consumption,¹⁷ cohabitation,¹⁸ employment,¹⁹ and body mass index (BMI).²⁰

The two groups were compared in terms of overall health measures. In principle, overall measures should better reflect the impact of stress than specific conditions because the latter would be more influenced by individual predispositions and vulnerabilities: by considering overall effects, the impact of stress should be revealed.

Overall health measures were: percentage of each group experiencing any potentially stress-related health condition (Prevalence), the number of days affected during the previous year (Persistence: N.B. to prevent an artefactual inflation due to Prevalence, Persistence was calculated as the mean days affected for those with any health condition—i.e. the total days affected divided by the number of conditions), and the percentage of those affected who took prescription medication (Medication).

Prevalence gives a measure of the overall health of each group, while Persistence and Medication Use provide evidence of the impact of the conditions.

Data analysis

Questionnaire data were analysed using Analysis of Covariance (ANCOVA) to allow comparison of the waiting list and CI groups while controlling for potentially confounding variables.

To explore the data further, where significant overall effects were observed, analyses were conducted at the level of the specific health conditions assessed. These were conducted using either t-tests (continuous outcomes) or Chi-squared tests (discrete outcomes). Since these analyses were exploratory and there was low statistical power due to the relatively low numbers experiencing each of the individual conditions, no attempt to correct type-I error rates for multiple testing was made.

Least-squares linear regression models for the two stressors (time on the waiting list and dissatisfaction with hearing) were established overall and for the waiting list and cochlear implant groups separately.

Four outcome measures were used: Prevalence (sum of conditions experienced), Persistence (average days affected), Medications, and DASS-total score. Stressors were included as predictors in separate models; all of these controlled for age, sex, living situation, and employment status.

3. RESULTS

No significant differences in age ($t[158]=.511$, $p=0.610$), sex (Chi-squared $[1, N=162]=1.207$, $p=0.179$), living situation (Chi-squared $[1, N=158]=.775$, $p=0.252$), or employment status (Chi-squared $[1, N=155]=1.444$, $p=0.154$) were found between the two groups (Table 1).

Those with cochlear implants had had their implant, on average, for 5.73 years ($SD=4.93$, Range: 375–6653 days) and they had, on average, spent approximately 9 months (mean=0.68 years, $SD=0.67$, Range: 8–1218 days) on the waiting list prior to their cochlear implant surgery. Those on the waiting list had been on the list, on average, for 18 months (mean=1.47 years, $SD=1.18$, Range: 45–1960 days).

Health

11% ($n=4$) of those on the waiting list and 6% ($n=7$) of those with cochlear implants were smokers (Chi-squared $[6, n=158]=4.552$,

Table 1. Demographic characteristics of participants by group

Variables		Waiting list	Cochlear implant
Age	Mean	60.2 (SD=17.9)	58.6 (SD=17.3)
Sex	Male	17 (39%)	57 (48%)
	Female	27 (61%)	61 (52%)
Living situation	Alone	9 (21%)	32 (28%)
	With others	34 (79%)	83 (72%)
Employment (full or part-time)	Employed	17 (40%)	58 (51%)
	Other	25 (60%)	55 (49%)

$p=0.602$). In regards to binge alcohol consumption, 27% of those on the waiting list and 28% of those with cochlear implants reported consuming five units of alcohol or more, on at least one day a week (Chi-squared [8, $n=157$]=8.307, $p=0.404$).

Of those on the waiting list, 55% were considered overweight or obese according to their BMI compared to 62% with cochlear implants (Chi-squared [2, $N=146$]=1.295, $p=0.523$).

Those on the waiting list visited their doctor an average of 6.2 (SD=4.8) times a year, whereas those using cochlear implants did so 4.3 (SD=3.7) times a year ($t(151)=2.616$, $p=0.010$). However, no significant differences between the two groups were found in days off work because of illness or bedridden days (both $p>0.4$).

General health

People on the waiting list were less likely to rate their health

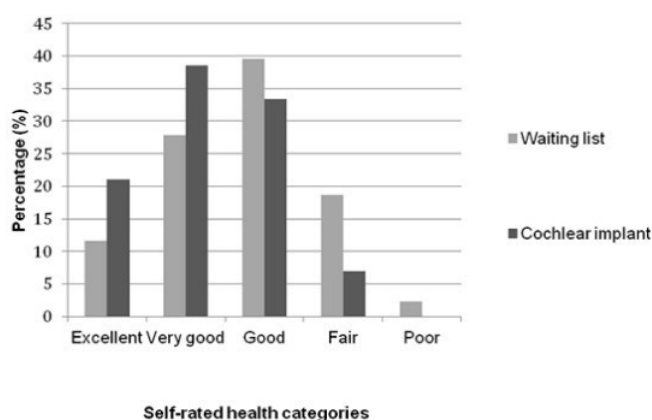


Figure 2. Self-rated general health perceptions of those on the waiting list for cochlear implantation compared to those with cochlear implants.

as very good or excellent and more likely to rate their health as poor, fair or good than people with cochlear implants (Chi-squared [4, $N=157$]=9.609, $p=0.048$; Figure 2).

Prevalence of potentially stress-related health conditions

People on the waiting list reported experiencing an average of 5.8 (SD=3.01) different health conditions in the past 365 days whereas those with cochlear implants reported an average of 4.5 (SD=2.70) conditions, ($F(1,161)=7.153$, $p=0.008$).

This difference remained after correcting for age, sex, living situation and employment, ($F(5,152)=5.525$, $p=0.020$). The distribution of the number of conditions experienced in the past year is shown in Figure 3.

Within this, tinnitus (Chi-squared [1, $N=160$]=5.758, $p=0.016$); diabetes (Chi-squared [1, $N=163$]=7.705, $p=0.006$); CVD (Chi-squared [1, $N=162$]=4.324, $p=0.038$) and hypertension (Chi-squared [1, $N=163$]=5.272, $p=0.022$) were all significantly more common in those on the waiting list than in those with CIs (Table 2).

No conditions were significantly more common in the cochlear implant user group than in the waiting list group (all $p>0.1$).

Persistence

When people on the waiting list were affected by a condition, they were affected for longer than those with cochlear implants ($F(1, 152)=11.604$, $p=0.001$).

The average number of days affected for those in the WL group was 164 days (SD=121 days) compared to 97 days (SD=103 days) for the cochlear implant group. This difference remained after correcting for age, sex, employment status and living situation, ($F(1, 142)=11.970$, $p=0.001$).

Additionally, digestive problems ($t(69)=2.154$, $p=0.035$), migraines (marginally) ($t(24)=1.913$, $p=0.068$); and tinnitus ($t(65)=2.830$, $p=0.006$) when experienced, occurred more frequently in the waiting list group than the cochlear implant group (Table 2). There was no difference between the two groups for any of the other individual conditions (all $p>0.1$).

Medication

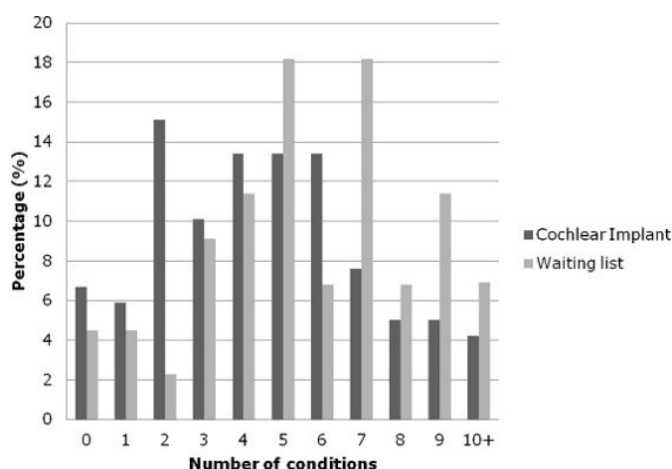


Figure 3. Distribution of number of potentially stress-mediated conditions experienced by CI-users and people on the waiting list for a CI.

People on the waiting list, on average, took prescription medication for 3.1 (SD=2.4) conditions whereas those with cochlear implants took prescription medication for 1.8 (SD=1.9) conditions ($F(1, 161)=12.602$, $p=0.001$). This difference remained after correcting for age, sex, living situation and employment, ($F(1, 146)=11.597$, $p=0.001$).

People on the waiting list were more likely to take prescription medication for migraines ($F(1,26)=4.984$, $p=0.034$), ear infections ($F(1, 19)=8.44$, $p=0.009$), and sleep disturbances ($F(1, 42)=9.990$, $p=0.003$) than those in the cochlear implant group (Table 2).

Mental health

The proportion of each group meeting the DASS-21 diagnostic

criterion for anxiety (Chi-squared $[1, 158]=5.699$, $p=0.016$), depression (Chi-squared $[1, 158]=3.874$, $p=0.042$), and stress (Chi-squared $[1, 158]=5.347$, $p=0.023$) was higher in those on the waiting list than in those using cochlear implants (Figure 4).

Total psychological distress, indicated by the total score on the DASS-21, was also increased in the waiting list group (Mean=22.9, SD =18.6) when compared to those with cochlear implants (Mean=15.4, SD=15.5), $F(1, 156)=6.560$, $p=0.011$. This difference remained after correcting for age, sex, living situation and employment, ($F[1, 144]=5.678$, $p=0.018$).

Dissatisfaction with hearing

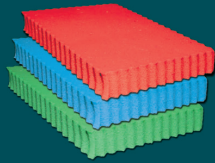
As would be expected, people on the waiting list had greater dissatisfaction with their hearing (Mann-Whitney $U = 142.5$, $p<.001$) than those on the waiting list (Figure 5).

Table 2. Specific health conditions

Health Condition	Number Responding		Prevalence (%)		Persistence (Days)		Medication (%)	
	Waiting List	CI Users	Waiting List	CI Users	Waiting List	CI Users	Waiting List	CI Users
Tinnitus	42	118	60*	38	308*	199	12	2
Hypertension	44	119	48*	29	280	237	94	90
Digestive symptoms	44	118	48	48	135*	62	71	63
Cold	44	119	48	49	6	9	30	23
Back Pain	43	119	42	42	140	108	65	43
Joint Pain	44	119	39	35	214	158	50	40
Neck Pain	44	119	34	28	142	72	54	31
Arthritis	44	119	25	17	349	309	50	53
Sleep problems	44	119	25	29	236	174	55*	12
Migraine	44	119	25	14	72**	19	64*	24
Ear infection	44	119	23	13	45	11	100*	46
Diabetes	44	119	21*	6	320	243	89	50
Influenza	44	119	21	19	5	10	50	39
Asthma	44	118	18	9	105	40	100	91
Chest infection	44	119	18	9	74	23	71	82
Cardiovascular Disease	43	119	16*	6	365	268	100	100
Heart palpitations	44	119	14	8	105	32	50	33
Skin problems	44	119	9	6	219	218	100	86
Thyroid disorder	44	119	7	2	365	365	100	100
Irritable Bowel Syndrome	44	119	7	9	365	139	50	55
Cancer	44	119	7	2	¾	¾	¾	¾
Stroke	44	119	2	1	¾	¾	¾	¾
Ulcer	44	119	0	3	¾	365	¾	100
Colitis	44	119	0	1	¾	0	¾	100
Other	44	119	25	21	¾	¾	¾	¾

Note: Prevalence (Percentage of group with any potentially stress-related health condition), Persistence (mean number of days experiencing potentially stress-related health conditions), and Medication (Percentage of group using medication to treat potentially stress-related health conditions). Asterisks indicate where the waiting list group had poorer health markers than the CI group. * $p<0.05$; ** $p<0.01$

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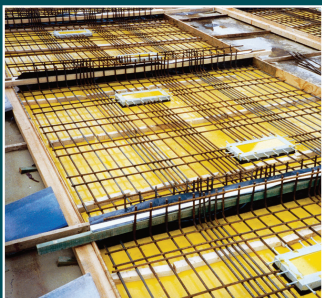
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Stressors prediction of health measures

Linear regression models controlling for age, sex, living situation and employment were run to examine the association between the potential stressors (Dissatisfaction with hearing and Time spent on the waiting list) and the four measures of health (Prevalence, Persistence, Medication, and DASS).

Dissatisfaction with hearing was associated with poorer health according to all four measures overall, but only with Persistence and Mental Illness in the CI group, and only (marginally) with Mental Illness in the Waiting List group (Table 3).

Time on the waiting list predicted greater Persistence and use of Medication overall, but was not related to Prevalence or Mental Illness, and was not associated with any of the health measures within the two groups separately (Table 3).

4. DISCUSSION

We showed that potentially stress-related health conditions had greater prevalence, illness persistence, and use of medications for in people on the waiting list. These findings are consistent with previous findings of an association between stress and illness.⁹

There was no a priori reason why waiting list candidates should have poorer health than CI users, and nor did controlling for potential confounding factors influence the effects; this implies that poorer health was attributable to the experience of living with acquired hearing loss and/or the experience of being on a waiting list for life-changing surgery.

Associations were stronger between dissatisfaction with hearing and the health measures, but time spent on the waiting list was also associated with health. This may imply that both are influential.

Prevalence, persistence, and medication

People on the waiting list had higher prevalence of stress-related conditions than those with a cochlear implant. The effects of stress on health vary between individuals, and may be mediated by predispositions such as genetics or previous illnesses.²¹

Thus, individuals who are undergoing similar stressors may develop different illnesses, and an overall indication of the total conditions experienced provides a stronger indication

of psychophysiologically-mediated illness than any individual condition alone. Basing analyses on the total conditions also avoids potential statistical power issues associated with the rarer conditions.

Health conditions were more persistent in those on the waiting list. On average, individuals on the waiting list, when affected by any condition, were affected for 164 days compared to 97 days for those with cochlear implants. The findings are consistent with earlier research showing stress to aggravate current conditions and delay recovery from illness.²²

The greater use of prescription medication in the waiting list group also indicates reduced health for this group. The differences in Persistence described above may have been greater had it not been for the medication used.

Smoking and binge alcohol consumption

The poorer health of those on the waiting list could be directly due to stress, or could be indirectly influenced by health-related behaviours common in people under stress, such as consumption of too much alcohol or smoking.²³ However, no differences were seen between the two groups in relation to smoking and binge alcohol consumption.

There were few smokers and binge alcohol drinkers in both groups, which is consistent with previous findings of low levels of alcohol consumption and smoking in the hearing-impaired population²⁴, and this gave only limited statistical power to detect any differences which may have been present.

Tinnitus

The rate of tinnitus was 60% in the waiting list group and 38% in the cochlear implant group. This difference of about one third is comparable to previous reports of decreases in tinnitus rates after cochlear implantation²⁵.

Tinnitus holds a particular place in the relationship between stress, hearing loss and illness. Firstly, as for many of the conditions, tinnitus can be caused by stress²⁶, and can also lead to stress,²⁷ resulting in a cycle of increasing illness and stress. Secondly, tinnitus can be caused by hearing loss⁴ or by stress.²⁶ Furthermore, cochlear implantation could reduce tinnitus via activation of the auditory pathways⁴ or by reducing stress²⁶.

Thus, unlike other conditions, there were two mechanisms that

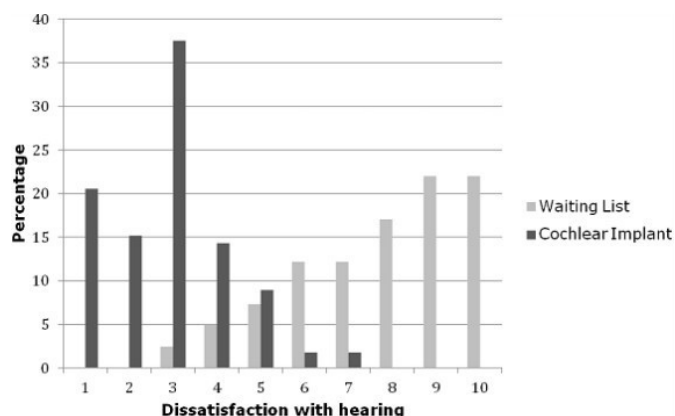


Figure 3. Distribution of number of potentially stress-mediated conditions experienced by CI-users and people on the waiting list for a CI.

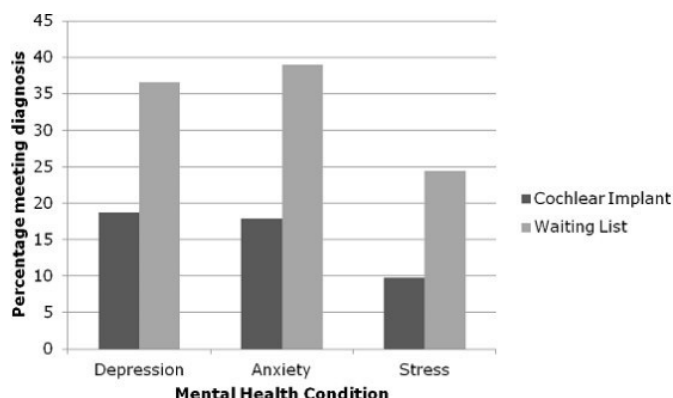


Figure 4. Percentage of each group meeting DASS-21 criteria for depression, anxiety, and stress.

may cause and reduce tinnitus. This may explain why tinnitus was the most commonly experienced condition in the waiting list group (stress plus hearing loss) and was also the condition with the greatest reduction following cochlear implantation (reduced stress plus auditory pathway activation).

Mental health

Symptoms of depression and anxiety²⁸ have previously been shown to improve following cochlear implantation. The current study adds further support for the mental health benefits of cochlear implantation as symptoms of all three facets (stress, depression, and anxiety) of the DASS were lower in those with cochlear implants than in those on the waiting list.

Dissatisfaction with hearing

Overall, dissatisfaction with hearing predicted poorer physical and mental health. This is consistent with the idea that impaired hearing would have an impact on health via isolation and frustration leading to chronic stress and thus impaired immune function.

The effects were less clear within the groups, but this would be explained by the reduced statistical power and the relative homogeneity of hearing within groups: the people on the CI waiting list all hear very poorly, so it is difficult to detect gradual effects amongst them.

Amongst the CI-users, there was rather more variability in functional hearing, and those who were still dissatisfied with their hearing also tended to have more persistent health problems and poorer mental health.

Time on waiting list

Overall, time spent on the waiting list was associated with more persistent health problems and greater use of medication, consistent with the idea that the waiting is stressful in itself. When psychophysiological changes persist through time, their effects add up and the risk of illness increases.²⁹ Increased waiting times for elective surgery have previously been associated with increased mental distress.³⁰

Implications of findings

The implications of this research are important: cochlear implantation is reliant on available funding (e.g. government, donations) because the cost of implantation and support is very high and is thus rarely covered by an individual recipient.

In New Zealand, public support of adult cochlear implantation is limited due to funding restrictions (for the Northern Cochlear Implant Programme, this has increased to 30 in the last 2 years). However, the increased presence and prolongation of illness in those on the waiting list will also burden the public health system. Thus, the true cost of cochlear implantation should take into account the consequent reduction of health system use and improved productivity.

Strengths and limitations

The main strengths of this research were that there were good and similar response rates for the two groups, and that the conditions assessed were all potentially mediated by stress. As far as we know, this is the first time that such differences have been observed in a CI/waiting list population, and the information may be valuable to policy-makers

It must be acknowledged that it is possible that some other factor(s) could lead to the observed differences in health. The research relied on self-report of health conditions, and those on the waiting list may have reported illness more readily than those with CIs for some unknown reason.

On the other hand, there was no obvious incentive for such behaviour, in that physical health state does not influence ranking on the waiting list, and the research was conducted independently and with anonymous questionnaires.

The research was cross-sectional and it cannot be ascertained that the health of the people on the waiting list was not already poor when they joined it. However, entry to the waiting list is permitted only if applicants are considered healthy enough to sustain an operation, and since entry to the waiting list is based primarily on hearing disability, there is no reason to suppose that the health, on entry to the waiting list, of current list members would have been poorer than those who have already received CIs.

Where present, associations between health measures and dissatisfaction with hearing and time on the waiting list were of the order of 0.2. These are small, but it must be borne in mind that our regression models controlled for potential confounding variables, and that many extraneous factors would be involved in influencing health. The effects are thus worthy of consideration, and the presence, rather than the magnitude of associations is of interest.

Table 3. Standardised linear regression coefficients (Beta) for the relationship between Stressors (Dissatisfaction with hearing and Time on waiting list) and Stress-related health measures. Models were run overall and for the CI and waiting-list groups separately. All models controlled for age, sex, living situation, and employment.

Variables	Dissatisfaction with Hearing			Time on Waiting List		
	Overall	Cochlear Implant Group	Waiting List Group	Overall	Cochlear Implant Group	Waiting List Group
Prevalence	0.189*	0.047	0.071	0.075	0.050	-0.066
Persistence	0.288**	0.209*	-0.039	0.200*	0.125	0.052
Medication	0.217**	0.040	0.044	0.198*	0.063	0.122
Mental Illness	0.291**	0.296**	0.380~	0.063	0.019	-0.196

Finally, while the conditions we considered were potentially stress mediated, we had no physiological markers of stress in the waiting list group other than their physical illnesses, and future research measuring physiological stress markers in both groups would be useful.

5. CONCLUSION

The findings of this research are important for two main reasons: they demonstrate the impact of long-term stress on both physical and mental health, and they imply that living with significant acquired hearing loss while waiting for a cochlear implant is detrimental to health.

Funding for adult cochlear implantation in New Zealand is limited, leading to lengthy waiting lists. Reduction of the waiting list time for cochlear implantation may contribute to the reduction of stress-associated medical conditions in those who have lost their hearing and thereby reduce the burden on the health system.

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