

Investigating tinnitus subgroups based on hearing-related difficulties

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Keywords

tinnitus, heterogeneity, subgroups, phenotyping, interventions, tinnitus management

What is already known about this topic

Due to the heterogeneity of tinnitus, variable outcomes are seen after intervention.

Subgrouping those with tinnitus may help to implement tailored interventions and reduce
outcome variability. Subgrouping has not previously been based on hearing-related
comorbidities.

What does this article add

Three distinct tinnitus subgroups were identified based on hearing-related comorbidities and tinnitus severity. These were a tinnitus-only group, individuals with tinnitus, hearing loss, hyperacusis and/or misophonia, and those with tinnitus and hearing loss only. Focusing on hearing-related variables that are relatively straightforward to identify by means of a short screening process can help triage tinnitus patients for clinical interventions.

Abstract

Purpose: Meaningfully grouping individuals with tinnitus who share the common characteristics (i.e., subgrouping, phenotyping) may help tailor interventions to certain tinnitus subgroups and hence reduce outcome variability. The purpose of this study was to test if the presence of tinnitus subgroups are discernible based on hearing-related comorbidities, and to identify predictors of tinnitus severity for each subgroup identified.

Methods: An exploratory cross-sectional study was used. The study was nested within an online survey distributed worldwide to investigate tinnitus experiences during the COVID-19 pandemic. The main outcome measure was the tinnitus Handicap Inventory- Screening Version

Results: From the 3400 respondents, 2,980 were eligible adults with tinnitus with an average age of 58 years ($SD= 14.7$) with 50% ($n= 1,457$) being female. A three-cluster solution identified distinct subgroups, namely, those with tinnitus but no hearing loss ($n = 1,306$; 44%), those presenting with tinnitus and hyperacusis and/or misophonia ($n = 795$; 27%), and those with tinnitus and hearing loss ($n = 879$; 29%). Those with tinnitus and hyperacusis reported the highest tinnitus severity ($M= 20.3$; $SD= 10.5$) and those with tinnitus and no hearing loss had the lowest tinnitus severity ($M= 15.7$; $SD= 10.4$). Younger age and the

presence of mental health problems predicted greater tinnitus severity for all groups ($\beta \leq -.1$, $p \leq .016$).

Conclusion: Further exploration of these potential subtypes are needed in both further research and clinical practice by initially triaging tinnitus patients prior to their clinical appointments based on the presence of hearing-related comorbidities. Unique management pathways and interventions could be tailored for each tinnitus subgroup.

Keywords

tinnitus, heterogeneity, subgroups, phenotyping, interventions, tinnitus management

What's already known about this topic?

Tinnitus is a very prevalent condition and can be very distressing. Numerous therapeutic approaches exist, but favourable outcomes are not always found. Due to tinnitus heterogeneity, it could be that subgroups of tinnitus exist who need differential treatments. Although phenotyping those with tinnitus has been attempted, there is no universally accepted tinnitus subgroups. This study aimed to export the presence of tinnitus subgroups based on hearing-related comorbidities.

What does this article add?

This study identified distinct subgroups, namely, those with tinnitus but no hearing loss, those presenting with tinnitus and hyperacusis and/or misophonia, and those with tinnitus and hearing loss. Those with tinnitus and hyperacusis reported the highest tinnitus severity and those with tinnitus and no hearing loss had the lowest tinnitus severity. Unique management pathways are suggested, tailored for each tinnitus subgroup.

100 **Introduction**

101 Tinnitus is defined as the sensation of sound in the absence of an external acoustic source,
102 although, at an individual level, the perception and reaction to these sounds varies widely [1].
103 The presence of tinnitus can affect sleep, listening, concentration, emotional wellbeing, and
104 quality of life [2,3]. For some individuals tinnitus can also contribute to anxiety and
105 depression [2,3]. There are thus variations of how bothersome tinnitus is and the associated
106 difficulties. Tinnitus is furthermore associated with a range of etiologies, further contributing
107 to it being a highly heterogeneous condition. Due to individual differences in patient factors,
108 variability in treatment outcomes are found. For clinicians, identifying what treatment is most
109 suited to each individual, who is most severely distressed by tinnitus and who is in need of
110 more intensive support is not always straightforward.

111 Sometimes a “one-size-fits-all” approach is taken when providing tinnitus
112 management [4] as it is not always clear who will benefit most from support and which type
113 of support should be offered [5]. The intervention provided is not always based on the
114 etiology or presenting difficulties, but rather on the available resources in certain geographic
115 locations [5]. For example, some professionals may focus on prescribing medication, largely
116 to address comorbidities often associated with tinnitus, such as insomnia, anxiety, and
117 depression [5]. Clinical psychologists usually provide psychological-based interventions,
118 such as cognitive behavioral therapy (CBT), mindfulness-based stress reduction (MBSR), or
119 acceptance and commitment therapy (ACT), but availability of trained psychologists who
120 specialize in tinnitus are scarce in many regions [6]. Audiologists tend to focus on addressing
121 hearing loss (difficulty hearing other speak clearly), often by fitting hearing devices [7].
122 There are also many who do not receive any help for their tinnitus, due to differences in
123 healthcare structures across countries, resulting in inequalities and inconsistent application of

published clinical guidance [8,9]. Patient experiences of tinnitus services is often low, leading to revolving-door healthcare [10].

The efficacy of most commonly used tinnitus interventions remains to be demonstrated [11]. The intervention with the most evidence of effectiveness is CBT, however, large effect sizes are seldom found [12,13]. Various formats of tinnitus interventions have also been used and contrasted including self-help (e.g. bibliotherapy) and guided-self-help (e.g. Internet-based approaches, group therapy, one-to-one therapy) [14,15] and combinations of approaches such as the tinnitus activities treatment [16]. To date, a single format or approach has not been identified to be fully effective for treating all tinnitus patients. This suggests that, due to tinnitus heterogeneity, a one-size-fits-all approach is unlikely to be effective. Therefore, individually tailored interventions may be more successful, however, guidelines on how such tailoring should be made are not presently available. As a first step, meaningfully grouping individuals with tinnitus who share the common characteristics (i.e., subgrouping) appears to be important to identify which patients are most likely to benefit from a particular treatment(s). Subgroup classification has previously been made by some research groups. For example, van den Berge and colleagues,[4] were unable to identify a cluster structure during analysis of 1,783 patients and concluded that tinnitus comprises a continuum rather than clearly defined subgroups. By comparison, Tyler and colleagues [17] performed cluster analysis on 246 participants. A four-cluster solution was found: (i) constant distressing tinnitus, (ii) tinnitus worsening in the presence of noise, (iii) copers without somatic modulation, and (iv) copers with tinnitus that worsens in quiet environments. Beukes and colleagues [18] sub-grouped 326 adults according to their tinnitus severity, based on self-reported scores as being mild, significant, or severe. In another recent study, Niemann and colleagues [19], examined 1,228 patients with chronic tinnitus using 14 questionnaires, and found four distinct subgroups, which included: (i)

149 avoidant group (56.8%), (ii) psychosomatic group (14.1%), (iii) somatic group (15.2%), and
 150 (iv) distress group (13.9%). On the other hand, Cederroth and colleagues [20] proposed that
 151 those with tinnitus differ on at least four dimensions: (i) perception, (ii) causal risk factors,
 152 (iii) related comorbidities, and (iv) the level of distress and the response to treatment. To our
 153 knowledge, none of these subgroups are widely used to assign patients to specified tinnitus
 154 treatments. Furthermore, these subgroups rely on individuals completing various specific
 155 outcome measures. An extensive test-battery approach is not always possible at primary care
 156 level due to limited time and resources and triaging is most easily based on common case
 157 history presentation [21].

158 It is clear that a gold standard diagnostic criterion for subgroup analysis remains
 159 elusive, suggesting that a different approach is required. One approach could be to study a
 160 larger, sample, instead of one based on patients from one clinic or area as has been the
 161 approach taken to date. Although subgrouping according to audiometric patterns of hearing
 162 function has been done [22], subgrouping according to the presence of additional hearing-
 163 related difficulties has not been attempted. The incidence of hearing-related commodities
 164 accompanying tinnitus is high. Hearing loss is a one of the greatest risk factor for developing
 165 tinnitus and prevalence studies suggest that hearing loss may be found in around 50% of
 166 adults with tinnitus [23]. Hyperacusis, related to a lower sound tolerance, is reported in up to
 167 40% of those with tinnitus [24]. The presence of misophonia, a condition in which certain
 168 sounds elicit disproportionately strong aversive reactions [25] has also been reported together
 169 with tinnitus and/or hyperacusis, but in smaller percentages (1-2%) [26].

170 Subgrouping according to hearing-related comorbidities may be clinically more
 171 viable, as the presence of hearing related issues are often part of standard case histories
 172 [4,19,24]. On this basis, to further explore possible tinnitus subtypes, the aim of this study
 173 was to expand on previous research by using a large heterogeneous sample, including both

clinical and non-clinical tinnitus populations from across the globe. The primary aim was to identify whether specific subgroups of tinnitus patients based on hearing-related comorbidities and tinnitus severity exist. A further aim was to ascertain predictors of tinnitus severity within these subgroups. The hypothesis was that unique groups would be identified that would differ in levels of tinnitus severity.

Materials and Methods

Study Design

An exploratory cross-sectional survey study design was used. This study was nested within a survey distributed world-wide to investigate tinnitus experiences during the COVID-19 pandemic in May-June 2020 [27]. Ethical approval was granted by Anglia Ruskin University (Cambridge, UK, reference number FSE/FREP/19/927) for international data collection, and ethical approvals from individual countries were also obtained. The STROBE reporting guidelines [28] were used to report the methods and results of the survey.

Data Collection

Eligibility criteria included adults aged 18 years and older reporting the presence of tinnitus. The survey was available in English, Dutch, Portuguese, Swedish, German, and Brazilian-Portuguese to enable global distribution. To reduce selection bias, recruitment targeted both clinical and non-clinical tinnitus populations and was distributed via patient organizations' social media outlets (i.e., Twitter, LinkedIn, and Facebook) and tinnitus clinics. Sample size calculations were based on estimates of 10% of the global adult population having tinnitus (700000000), indicating 1842 participants are required for a confidence level of 99% and error margin of 3%. The survey was distributed online via Qualtrics.

The primary outcome was tinnitus severity as measured by the Tinnitus Handicap Inventory Screening version (THI-S) [29] consisting of 10 questions, and based on the full version consisting of 25 questions. Scoring was between 0–40, with higher scores indicating more severe tinnitus.

To investigate tinnitus subgroups and predictors of tinnitus severity the following self-reported information was gathered:

- i) Demographics, such as age, gender, nationality, ethnicity, time since tinnitus onset, use of hearing aids and professional help sought for tinnitus.
- ii) The presence or absence of other hearing-related difficulties (e.g., hearing loss, hyperacusis, and/or misophonia).
- iii) The presence or absence of additional physical health problems (e.g., hypertension, back or neck pain, etc.).
- iv) The presence or absence of mental health problems (i.e., anxiety, depression, or other psychiatric disorders).

Data Analysis

Cases were initially removed if they did not meet study eligibility due to not having tinnitus or not completing the questions related to tinnitus on the questionnaire. All analyses were completed in the Statistical Package for Social Sciences (SPSS) version 26.0. Significance was set to $p \leq .05$, two-tailed. Post-hoc tests were Bonferroni corrected for multiple comparisons. Continuous data are expressed as mean and standard deviation. Categorical data are shown as percentages and frequencies.

Cluster analysis was first used to identify groups of individuals with tinnitus that had other hearing-related difficulties (i.e., hearing loss, hyperacusis, misophonia). As such, the selection of variables for cluster analysis were based on “expert opinion” (i.e., variables related to hearing-related difficulties presumed to be clinically relevant and discriminative in people with tinnitus). A two-step cluster analysis method was used, which is a hybrid approach that first uses a pre-clustering distance measure to identify separate groups, and then applies a probabilistic approach (similar to latent class analysis) to select an optimal subgroup model [30,31]. This exploratory method is most suited for analysis of large data sets, as well as analysing atypical values (or outliers). In addition, this cluster analysis approach is considered one of the most reliable and reproducible [30,31,32]. As each measure of hearing-related difficulties was dichotomous (i.e., yes/no), only categorical variables were entered in the analysis. The number of clusters to be formed was not specified *a priori*. The *silhouette measure of cohesion and separation* [33] was used as a measure for the overall goodness-of-fit of the cluster structure, which ranges from –1 to 1 (<0.25: *no substantial structure*; 0.26–0.50: *weak structure*; 0.51–0.70: *reasonable structure*; 0.71–1.0: *strong structure*).

Differences in characteristics between clusters were then compared according to the cluster membership variable using univariate analysis of variance (ANOVA) or Pearson’s Chi-squared tests for continuous and categorical variables, respectively. In addition, multivariable linear regression analyses tested whether the individual characteristics collected for this study during data analysis predicted tinnitus severity separately for each cluster.

Results

Sample Characteristics

There were 3,400 respondents of which 2,980 were eligible for inclusion for this analysis. The mean age of all respondents was 58 years ($SD= 14.7$), and 49% ($n= 1,457$) were females (Table 1). Respondents were predominantly from North America ($n= 1,497$; 50%), mainland Europe ($n= 707$; 24%) or the United Kingdom ($n= 684$; 23%). The average tinnitus severity score on the THI-S was 17 ($SD= 10.5$), suggesting the sample included a range of those with bothersome and non-bothersome tinnitus. Less than half of respondents had sought help for their tinnitus ($n= 1,151$; 39%). In addition to tinnitus, individuals reported that they also experienced hearing loss, hyperacusis and/or misophonia in various combinations, i.e., tinnitus, hearing loss and hyperacusis, or tinnitus, hyperacusis and misphonia as seen in Table 1. To the question: Which device/s do you use to help you with your hearing-related difficulties and/or tinnitus? 41% ($n= 1,230$) of respondents used hearing aids. However, 12% ($n= 364$) of individuals who reported wearing hearing aids did not report having hearing loss, suggesting that hearing aids may have been fitted due to the presence of tinnitus for sound therapy.

Table 1. Individual characteristics across all respondents with tinnitus completing the online questionnaire, as well as for each cluster identified in the cluster analysis. Clusters represent (1) tinnitus-only; (2) tinnitus, hearing loss, hyperacusis and/or misophonia; and (3) tinnitus and hearing loss only.

Characteristic	Overall N= 2,980	Cluster 1 (n = 1,306)	Cluster 2 (n = 795)	Cluster 3 (n = 879)
	Mean (SD)			
Age	58 (14.7)	57 (14.7)	57 (14.7)	62 (13.9)
Tinnitus duration in years since onset	13 (13.9)	11 (12.3)	14 (13.7)	17 (15.4)
Tinnitus severity (score range 0-40)	17 (10.5)	16 (10.4)	20 (10.5)	17 (10.1)
	Number (%)			
Gender				
	<i>Female</i> 1,457 (48.9)	575 (44.0)	463 (58.2)	419 (47.7)

	<i>Male</i>	1,490 (50.0)	719 (55.1.)	322 (40.5)	449 (51.1)
	<i>Gender diverse</i>	18 (0.6)	7 (0.5)	7 (0.9)	4 (0.5)
	<i>Unspecified</i>	15 (0.5)	5 (0.4)	3 (0.4)	7 (0.8)
Nationality					
	<i>North America</i>	1,497 (50.2)	635 (48.6)	372 (46.8)	490 (55.7)
	<i>Mainland Europe</i>	707 (23.7)	310 (23.7)	244 (30.7)	153 (17.4)
	<i>United Kingdom</i>	684 (23.0)	304 (23.3)	160 (20.1)	220 (25.0)
	<i>South America</i>	54 (1.8)	36 (2.8)	8 (1.0)	10 (1.1)
	<i>Asia</i>	14 (0.5)	7 (0.5)	5 (0.6)	2 (0.2)
	<i>Africa</i>	12 (0.4)	7 (0.5)	2 (0.3)	3 (0.3)
	<i>Australia</i>	12 (0.4)	7 (0.5)	4 (0.5)	1 (0.1)
Ethnicity					
	<i>Caucasian</i>	2,750 (92.3)	1,184 (90.7)	731 (91.9)	835 (95.0)
	<i>Asian</i>	56 (1.9)	32 (2.5)	10 (1.3)	14 (1.6)
	<i>Hispanic</i>	52 (1.7)	28 (2.1)	15 (1.9)	9 (1.0)
	<i>Black</i>	47 (1.6)	28 (2.1)	10 (1.3)	9 (1.0)
	<i>Mixed/Multiple</i>	38 (1.3)	15 (1.1)	16 (2.0)	7 (0.8)
	<i>Native Hawaiian</i>	10 (0.3)	7 (0.5)	1 (0.1)	2 (0.2)
	<i>American Indian</i>	5 (0.2)	2 (0.2)	2 (0.3)	1 (0.1)
	<i>Unspecified</i>	22 (0.7)	10 (0.8)	10 (1.3)	2 (0.2)
Additional physical health problems reported*		1,681 (56.4)	667 (51.1)	484 (60.9)	530 (60.3)
	<i>Hypertension</i>	659 (22.1)	285 (21.8)	159 (20.0)	215 (24.5)
	<i>Chronic neck/back pain</i>	512 (17.2)	186 (14.2)	178 (22.4)	148 (16.8)
	<i>Osteoarthritis</i>	427 (14.3)	153 (11.7)	128 (16.1)	146 (16.6)
	<i>Chronic allergy</i>	328 (11.0)	84 (6.4)	114 (14.3)	130 (14.8)
	<i>Thyroid disease</i>	263 (8.8)	109 (8.3)	90 (11.3)	64 (7.3)
Additional mental health problems *		1,258 (42.2)			
	<i>Anxiety</i>	876 (29.4)	344 (26.3)	306 (38.5)	226 (25.7)
	<i>Depression</i>	833 (28.0)	297 (22.7)	282 (35.5)	254 (28.9)
	<i>Other psychiatric disorder</i>	122 (4.1)	34 (2.6)	57 (7.2)	31 (3.5)
Sought treatment for tinnitus		1,151 (38.6)	459 (35.1)	372 (46.8)	320 (36.4)
Presence of hearing loss only			0 (0)	0 (0)	879 (100)
Presence of hyperacusis only			0 (0)	298 (37.5)	0 (0)
Presence of misophonia only			0 (0)	26 (3.3)	0 (0)
Presence of hearing loss and hyperacusis			0 (0)	353 (44.4)	0 (0)
Presence of hearing loss and misophonia			0 (0)	18 (2.3)	0 (0)
Presence of hyperacusis and misophonia			0 (0)	46 (5.8)	0 (0)
Presence of hearing loss, hyperacusis and misophonia			0 (0)	54 (6.7)	0 (0)
Hearing aid wearer		1230 (41.3%)	0 (0)	345 (43.4)	600 (68.3)

*Multiple problems reported by the same participant at times.

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267

268 Cluster Analysis

269 The outcome of the cluster analysis was a three-cluster solution: *cluster one* (n= 1,306;

270 43.8%) consisted of individuals with tinnitus-only; *cluster two* (n= 795; 26.7%) consisted of

271 individuals with tinnitus and hyperacusis, and/or misophonia; and *cluster three* (n = 879;
272 29.5%) were individuals with tinnitus and hearing loss only. Misophonia was the least
273 predictive factor and did not differentiate the clusters. The *silhouette measure of cohesion*
274 *and separation* was 0.80, indicating a strong cluster structure.

275 All variables differed significantly between clusters, with all omnibus and post hoc
276 pairwise group comparisons $p < .001$ (Table 1 and Figure 1). Individuals in cluster three were
277 older, experienced tinnitus for the longest duration, and were more likely to wear hearing
278 aids,. A higher proportion of individuals in cluster two were female, reported mental health
279 problems; had greater tinnitus severity; and had sought treatment for their tinnitus. A higher
280 proportion of individuals in both clusters two and three reported experiencing physical health
281 problems.

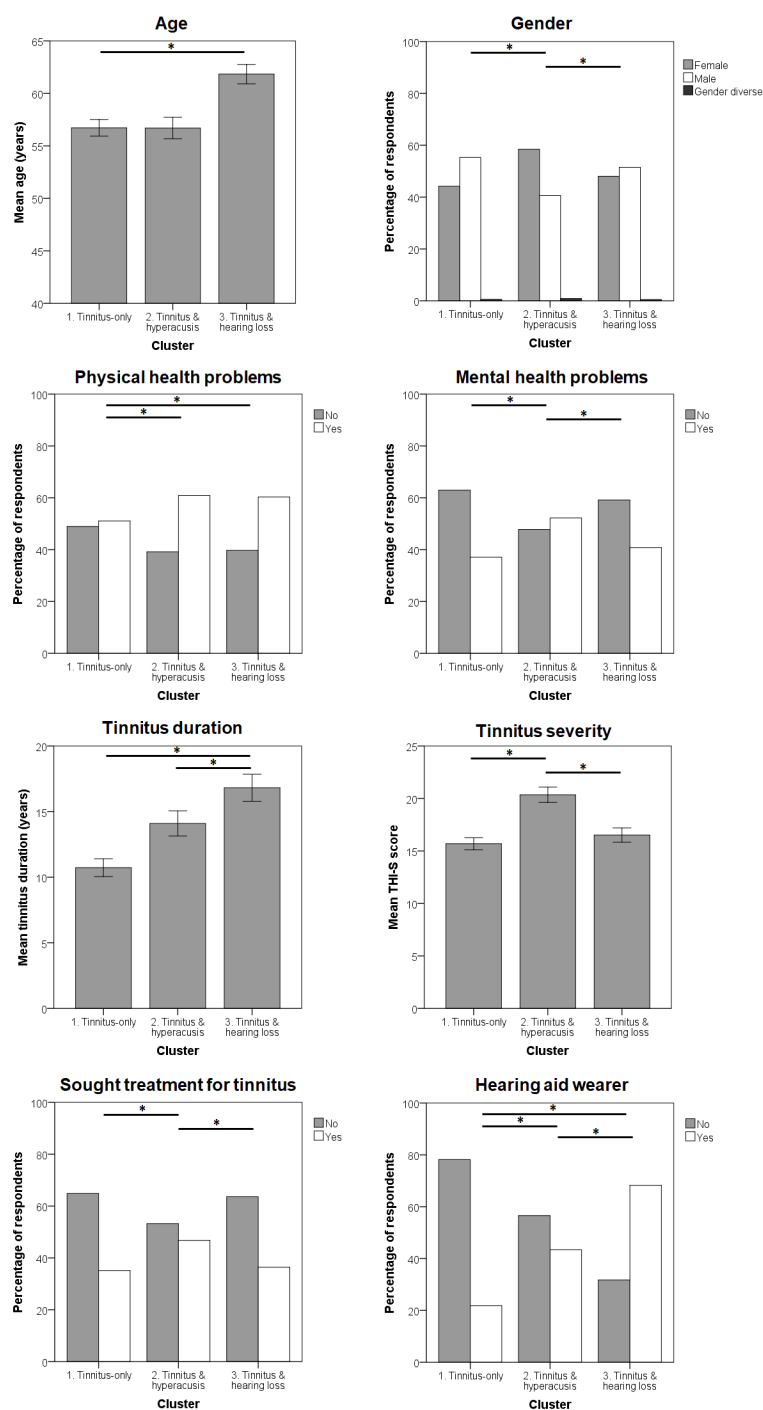


Figure 1: Individual characteristics for each cluster identified: (1) tinnitus-only, (2) tinnitus, hearing loss, hyperacusis and/or misophonia, and (3) tinnitus and hearing loss only. Characteristics labelled A to H include: age, gender, physical health problems, mental health problems, time since the onset of tinnitus, tinnitus severity, sought treatment for tinnitus, and hearing aid wearer, respectively. Error bars represent 95% confidence intervals. THI-S= Tinnitus Handicap Inventory-Screening. * $p < .001$, Bonferroni corrected for multiple comparisons.

Multiple Linear Regression Analysis

To determine whether any variables predicted greater tinnitus severity for each cluster, all individual characteristics (e.g., age, gender, tinnitus duration, etc.) were entered into a single regression model. As shown in Table 2, for cluster one (tinnitus-only), younger age, presence of physical health problems, presence of mental health problems, seeking treatment for tinnitus, and being a hearing aid wearer significantly predicted greater tinnitus severity. For cluster two (tinnitus, hearing loss, hyperacusis and/or misophonia), younger age and presence of mental health problems predicted greater tinnitus severity. For cluster three (tinnitus & hearing loss only), younger age, presence of mental health problems, shorter tinnitus duration since onset, and seeking treatment for tinnitus predicted greater tinnitus severity. In an attempt to draw clinically meaningful inferences from these results, possible considerations regarding these subgroups are provided in Table 3 to aid the planning of further research and clinical interventions. This has shown that there are some defining characteristics for each cluster. Individuals with tinnitus and hyperacusis are more likely to have higher tinnitus severity than those with only tinnitus or tinnitus and hearing loss. Thus, those with tinnitus and hyperacusis may require a timely appointment and may need to be seen by a tinnitus and hyperacusis specialist. Those in cluster 3 with tinnitus and hearing loss should have their hearing addressed to ensure this does not add to their disability. Those with tinnitus only may not benefit from hearing aid use, and such use may be detrimental. Other approaches such as psychological based therapies should thus be considered.

Table 2. Summary of multiple linear regression analysis for tinnitus severity predicted by individual characteristics (age, gender, physical health problems, mental health problems, tinnitus duration since onset, sought treatment for tinnitus, hearing aid

wearer) for each cluster. Bold indicates $p < .05$. β = standardized coefficient, CI = confidence interval.

Cluster	Characteristic	β	t	p -value	95% CI
1. <i>Tinnitus-only</i>	(Constant)		13.02	<.001	16.89, 22.88
	Age	-0.16	-5.15	<.001	-0.16, -0.07
	Gender	-0.02	-0.60	.549	-1.45, 0.77
	Physical health problems	0.07	2.22	.027	0.16, 2.59
	Mental health problems	0.19	6.88	<.001	2.88, 5.19
	Tinnitus duration since onset	-0.04	-1.48	.140	-0.08, 0.01
	Sought treatment for tinnitus	0.67	2.36	.018	0.25, 2.71
	Hearing aid wearer	0.09	3.37	.001	1.02, 3.88
2. <i>Tinnitus & hyperacusis</i>	(Constant)		10.09	<.001	16.88, 25.04
	Age	-0.10	-2.40	.016	-0.13, -0.01
	Gender	0.03	0.80	.422	-0.86, 2.04
	Physical health problems	-0.00	-0.11	.912	-1.70, 1.52
	Mental health problems	0.20	5.56	<.001	2.71, 5.67
	Tinnitus duration since onset	-0.04	-1.08	.280	-0.09, 0.03
	Sought treatment for tinnitus	0.06	1.48	.139	-0.39, 2.76
	Hearing aid wearer	0.03	0.77	.443	-0.92, 2.11
3. <i>Tinnitus & hearing loss</i>	(Constant)		11.52	<.001	18.66, 26.32
	Age	-0.15	-4.00	<.001	-0.16, -0.56
	Gender	-0.05	-1.47	.142	-2.31, 0.33
	Physical health problems	0.06	1.69	.091	-0.19, 2.57
	Mental health problems	0.21	6.29	<.001	2.91, 5.56
	Tinnitus duration since onset	-0.07	-2.14	.033	-0.09, -0.01
	Sought treatment for tinnitus	0.11	2.99	.003	0.76, 3.68
	Hearing aid wearer	-0.02	-0.67	.505	-1.85, 0.91

Table 3. Summary of the characteristics for each subgroup and suggested intervention

guidelines based on these subgroups.

	Cluster 1: Tinnitus only	Cluster 2: Tinnitus together with hyperacusis	Cluster 3: Tinnitus together with hearing loss
Characteristics			
Defining characteristics	<ul style="list-style-type: none"> Tinnitus not accompanied by physical health or additional mental health problems 	<ul style="list-style-type: none"> Female Additional physical health problems 	<ul style="list-style-type: none"> Older Longer tinnitus duration Additional physical health problems
Level of tinnitus severity	<ul style="list-style-type: none"> Lowest severity 	<ul style="list-style-type: none"> Highest severity 	<ul style="list-style-type: none"> Moderate severity

Contributions to tinnitus severity	<ul style="list-style-type: none"> ▪ Younger ▪ Additional mental health and physical problems ▪ Hearing aid use ▪ Tinnitus treatment sought 	<ul style="list-style-type: none"> ▪ Younger ▪ Additional mental health problems 	<ul style="list-style-type: none"> ▪ Younger ▪ Additional mental health problems ▪ More recent tinnitus onset ▪ Tinnitus treatment sought
Intervention suggestions			
Triaging	<ul style="list-style-type: none"> ▪ To professionals/ interventions covering approaches such as relaxation or psychological based approaches 	<ul style="list-style-type: none"> ▪ A timely appointment with a hyperacusis and tinnitus specialist/ intervention 	<ul style="list-style-type: none"> ▪ Initially to a hearing-related professional to address hearing loss
Possible intervention focus	Hearing devices may not be helpful. Approaches other than sound-based interventions such as psychological approaches may be helpful	Including psychological approaches due to high level of mental health difficulties	Prior to tinnitus interventions, ensuring well fitted hearing devices appropriately set to improve hearing clarity and decrease the starkness of the tinnitus percept
Possible intervention format	May be considered for self-help or guided self-help approaches	May benefit from guided professional support due to higher levels of tinnitus distress and mental health concerns	Following hearing aid fittings, self-help or guided self-help approaches could be considered
Additional referrals		As indicated, to consider wider referrals for additional health/ mental health concerns	As indicated, to consider wider referrals for additional health/ mental health concerns

323 **Discussion**

324 Although tinnitus is often accompanied by hearing loss and/or hyperacusis, subgrouping
 325 according to the presence of additional hearing-related comorbidities has not previously been
 326 attempted. The aim of this study was to identify whether specific subgroups of tinnitus
 327 patients, based on hearing-related comorbidities, exist. A further aim was to ascertain
 328 predictors of tinnitus severity within these subgroups. This research has expanded on
 329 previous research, using a large global sample from both clinical and non-clinical tinnitus
 330 populations.

331
 332 Cluster analysis identified three unique subgroups, a tinnitus-only group, individuals with
 333 tinnitus, hearing loss, hyperacusis and/or misophonia, and those with tinnitus and hearing loss
 334 only. Individual characteristics differed significantly for each subgroup. The tinnitus, hearing
 335 loss, hyperacusis and/or misophonia group were more likely to be female, have greater
 336 tinnitus severity, have additional mental health problems, and have sought treatment for their
 337 tinnitus compared with individuals presenting with tinnitus-only or those with tinnitus and
 338 hearing loss. Tinnitus severity, the presence of hyperacusis and mental health problems
 339 appear to be important characteristics to consider during subgrouping, as has also been
 340 suggested previously [34]. Moreover, the current study findings are consistent with previous
 341 tinnitus phenotype studies, which have suggested that the tinnitus subgroups vary in terms of
 342 tinnitus severity, psychological symptoms, stress, coping attributes, quality of life, and socio-
 343 demographic factors [19].

344 During subgrouping, Tyler and colleagues [17] categorized Cluster 1 as those with
 345 constant distressing tinnitus. In comparison to the other three clusters found, this group had
 346 hyperacusis, more severe tinnitus, anxiety, depression, emotional difficulties, and sleep
 347 problems. Although categorized differently, the characteristics of this cluster is similar to the

cluster in the present study of those with tinnitus, hearing loss, hyperacusis and/or misophonia. Subgrouping according to the presence of hyperacusis appears to indicate a unique group with more severe presentation of tinnitus and a greater prevalence of anxiety and depression. A general population study from Sweden [35], found hyperacusis to be more commonly associated with females and past help-seeking for their symptoms. Interestingly, this has also been noted in chronic pain research, indicating a higher prevalence of chronic pain and help-seeking in women [36,37]. It is noteworthy that, greater help-seeking was identified in the group with hyperacusis in comparison to the other groups. Hyperacusis can cause significant problems but is an area that has received little attention, particularly, regarding therapeutic interventions [38] although some exist [e.g., 39].

Individuals with tinnitus and hearing loss only were found to be older, have a longer time since the onset of tinnitus, and were more likely to wear hearing aids compared with tinnitus-only individuals or those with tinnitus, hearing loss, hyperacusis and/or misophonia. Both subgroups of those with tinnitus and hearing loss and those with tinnitus, hearing loss, hyperacusis and/or misophonia were likely to experience significantly more physical health problems compared with the tinnitus only individuals. The association of tinnitus with other health problems is important to investigate, as these problems can have additive effects as stressors, possibly leading to social isolation and lower quality of life [40]. A multidisciplinary approach including physiotherapy may be helpful [41].

Being younger and the presence of additional mental health problems predicted greater tinnitus severity for all three subgroups. These may be important screening criteria when triaging patients for tinnitus interventions. For the tinnitus and hearing loss only subgroup, significantly greater tinnitus severity was found for those with a more recent onset of tinnitus and those who had sought treatment for their tinnitus. For the tinnitus-only

subgroup, significantly greater tinnitus severity was also present for those with additional physical health problems, seeking treatment for tinnitus, and being a hearing aid wearer. A common management strategy for those with hearing impairment and tinnitus is the use of combination devices (amplification and sound generation), with the aim of decreasing the starkness between silence when in quiet situations and hearing tinnitus. A scoping review found significant differences between clinics regarding the fitting of hearing aids and combination devices [42]. This was attributed to practice guidelines not providing clarity regarding candidature or prescription of such devices. While evidence-based recommendations remain elusive, combination devices could be fitted inappropriately. When comparing clinical guidelines from different countries, the use of hearing aids for those with tinnitus are only recommended when clinically meaningful hearing loss is also present [8,9]. Those with tinnitus-only may benefit from management approaches that are not solely focused on use of hearing aids, such as psychological management approaches (e.g., relaxation, CBT, MSBR, ACT).

Limitations

This study focused only on selected factors associated with tinnitus severity in support of triaging patients prior to clinical investigation. The variance explained by our regression analyses was low, suggesting that other additional variables not considered may have been more predictive. This population may not be typical of a clinical tinnitus population who would have more bothersome tinnitus. People with tinnitus who rated the severity as very low and indicated that the tinnitus was not bothersome were included in this sample. Grouping tinnitus according to tinnitus descriptions, for instance the type of tinnitus (i.e., pulsatile, non-pulsatile, objective, subjective) pitch or type of noise [43,44], was not used in this study. The findings are only limited to those of this sample, which may not represent a more global

tinnitus population, as the majority of the responses were from the US and Europe. The data was collected during the COVID-19 pandemic which may have increased anxiety and depression, hence skewing the results. Findings are based only on self-reported survey data without any clinical data, such as verifying the type and degree of hearing loss through pure tone audiometry testing. Furthermore, standardized measures of anxiety and depression were not included. For this reason, it is possible that some questions were misread or misinterpreted and hence not accurately answered.

Clinical Implications and Further Directions

This study has focused on variables that are relatively straightforward to identify by means of a short screening process prior to seeing tinnitus patients clinically. Testing whether this way of subgrouping tinnitus is meaningful in clinical practice should be further explored. Based on these findings, exploring if specific tinnitus treatments are more effective for each subgroup should be investigated. Clinical trials can be structured to subgroup patients into these subgroups, instead of grouping all tinnitus patients into one group. A recent clinical trial for instance stratified according to atonal tinnitus, hyperacusis, normal hearing and noise-induced hearing loss [45]. This may provide some guidance regarding which interventions and which intervention approaches or formats may be most helpful to certain tinnitus subgroups. This exploratory study can be used to develop research protocols to further our understanding of tinnitus subgroups, perhaps using artificial intelligence. It highlights that individuals with tinnitus require tailored interventions, such as progressive tinnitus management (PTM), which triages patients according to tinnitus distress [46, 47]. These findings may aid with this triaging process and hence aid planning more effective tinnitus management pathways. Effective service provision is becoming increasingly

important as the with current trends suggesting that the prevalence of tinnitus is on the rise [48].

Figure and Table legends

Table 1. Individual characteristics across all respondents with tinnitus completing the online questionnaire, as well for each cluster identified in the cluster analysis. Clusters represent (1) tinnitus-only; (2) tinnitus, hearing loss, hyperacusis and/or misophonia; and (3) tinnitus and hearing loss only.

Table 2. Summary of multiple linear regression analysis for tinnitus severity predicted by individual characteristics for each cluster.

Table3. Summary of the characteristics for each subgroup and suggested intervention guidelines based on these subgroups.

Figure 1: Individual characteristics for each cluster identified: (1) tinnitus-only, (2) tinnitus, hearing loss, hyperacusis and/or misophonia, and (3) tinnitus and hearing loss only. Characteristics labelled A to H include: age, gender, physical health problems, mental health problems, time since the onset of tinnitus, tinnitus severity, sought treatment for tinnitus, and hearing aid wearer, respectively. Error bars represent 95% confidence intervals. THI-S= Tinnitus Handicap Inventory-Screening. * $p < .001$, Bonferroni corrected for multiple comparisons.

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Conflicts of interest/Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' contributions This study was conceptualized by EB. Data collection was by EB, VM, GA, VK, LJ, ML, JO, and DS. Data analysis and interpretation was by DM and EB and drafting the article was done by EB. All authors critically revised the article and approved the version to be published.

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