

Barriers to the Adoption of Mobile Tinnitus Management Tools in Diverse Populations: A Mixed-Methods Analysis of Socio-Demographic Influences, User Heterogeneity, and Pathways to Inclusive Digital Intervention

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Abstract — Mobile applications for tinnitus management have proliferated rapidly, yet their real-world adoption remains strikingly low. A mixed-methods study, combining sentiment analysis of 13,096 user reviews from 42 tinnitus applications, a cross-sectional survey of 171 adults with self-reported tinnitus, and in-depth semi-structured interviews with 19 participants, was conducted to investigate the socio-demographic and systemic barriers that prevent diverse populations from adopting these tools. Only 8.6% of survey respondents reported active app use despite the availability of 42 identified applications. Chi-square tests confirmed no statistically significant association between app adoption and either age ($\chi^2 = 6.25$, $df = 4$, $p > .05$) or gender ($\chi^2 = 0.42$, $df = 4$, $p > .05$), indicating that barriers are systemic rather than demographic. A point-biserial correlation demonstrated a very strong positive relationship between app use and subjective well-being ($r_{pb} = 0.82$, $p < .001$). Contrary to stereotypes, adults aged 30-49 years and full-time employed professionals constituted significant proportions of app users, challenging the assumption that tinnitus apps are used primarily by elderly retirees. Five principal barriers were identified through thematic analysis: low awareness and absent clinician referral pathways, lack of marketplace quality standardisation, limited personalisation, digital literacy challenges for older users, and privacy and data security concerns. Actionable recommendations are proposed for developers, clinicians, and policymakers to create user-centred, inclusive digital interventions that close the efficacy-accessibility gap in tinnitus self-management.

Keywords— tinnitus; mobile applications; digital health; barriers to adoption; inclusive design

I. INTRODUCTION

Tinnitus is a chronic auditory disorder characterised by the subjective perception of phantom sounds, ringing, buzzing, humming, or chirping, in the absence of an external acoustic stimulus (Anwar, 2013; Vasilescu & Weisman, 2023). In the United Kingdom, approximately one in seven adults is affected, representing an estimated 10-15% of the general population (Tinnitus UK, 2023). In the United States, approximately 50 million Americans are affected (Lynch, 2024). Globally, the condition places an immense socioeconomic burden on healthcare systems (Mazurek et al., 2023; Ruan et al., 2023).

Despite the absence of a universal cure (Draper et al., 2023; Vona, 2022), mobile health (mHealth) applications have emerged as a rapidly expanding channel for tinnitus self-management. These applications deliver sound therapy, cognitive behavioural therapy exercises, guided meditation, psychoeducation, and symptom monitoring, making them

theoretically well-suited to the psychosocial and perceptual burden of the condition (Galetsi et al., 2023; Langguth et al., 2019). Systematic reviews have documented this proliferation: Smith and Sereda (2020) identified nearly 250 tinnitus-related apps on major app stores, while Mehdi et al. (2020a) identified 74 apps meeting inclusion criteria in a formal systematic review.

However, despite this proliferation, the real-world adoption of tinnitus management apps remains strikingly low. The present study found that 91.4% of 171 surveyed tinnitus patients had never used a mobile application for tinnitus management (see Figure 1). This non-adoption paradox, whereby effective tools are largely unused by those who need them, constitutes the central empirical and policy challenge addressed in this paper. Prior research has examined the features, usability, and clinical efficacy of individual apps (Kutyba et al., 2022; Mehdi et al., 2020b; Yoon et al., 2023) but has largely neglected the

structural and socio-demographic determinants of non-adoption.

Critically, existing assumptions about the demographics of tinnitus app users have tended to position tinnitus as primarily a condition of older adults, with the expectation that low digital literacy would limit app uptake among elderly groups. The present study challenges this assumption by demonstrating a user profile that is heterogeneous across age and occupation, with younger professionals in high-pressure employment emerging as significant adopters. This paper investigates the socio-demographic and systemic barriers to adoption across diverse populations, and provides actionable evidence-based recommendations for developers, clinicians, and policymakers.

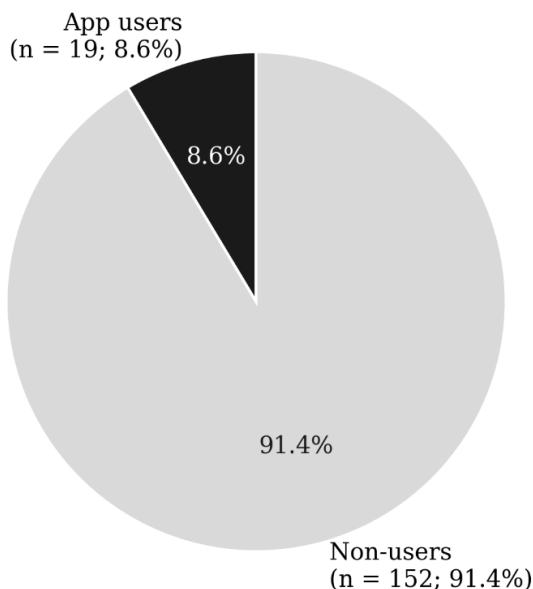


Figure 1. Mobile application adoption status among survey participants (N = 171).

Only 8.6% (n = 19) reported active use of a tinnitus management mobile application.

Background

Tinnitus and the Unmet Need for Self-Management

Tinnitus is classified into subjective tinnitus (perceived only by the patient; approximately 95% of cases) and objective tinnitus (detectable by external instruments; approximately 5% of cases) (Vasilescu & Weisman, 2023). The condition is strongly associated with sleep disturbance, anxiety, depression, and diminished quality of life (Hall et al., 2016; Tyler et al., 2018). Management encompasses pharmacotherapy, sound therapy,

tinnitus retraining therapy, cognitive behavioural therapy, and mindfulness-based interventions, all of which require sustained engagement that is difficult to maintain outside clinical settings (Cima et al., 2019; Hoare et al., 2014). The proliferation of smartphones has created an unprecedented opportunity to deliver these interventions at scale (Pryss et al., 2015; Searchfield et al., 2021), yet adoption remains far below its potential.

The Digital Health Adoption Challenge

Digital health adoption research has consistently demonstrated a paradox: while health apps are increasingly sophisticated and clinically efficacious under trial conditions, real-world uptake remains limited (Rakshit et al., 2021; Vahdat et al., 2021). Barriers commonly identified in the broader mHealth literature include low awareness, interface complexity, privacy concerns, lack of clinician endorsement, cost, and insufficient evidence-based content (Schoeppe et al., 2016; Villinger et al., 2019). For tinnitus specifically, an unregulated marketplace of several hundred apps of varying quality compounds user uncertainty (Mehdi et al., 2020a; Sereda et al., 2019). Deshpande and Shimunova (2019) identified that misinformation-laden tinnitus apps pose active hazards to patients, while Sereda et al. (2019) found awareness and discoverability to be primary limitations.

Demographic Assumptions and Their Limitations

The prevailing assumption in the tinnitus literature has been that the condition predominantly affects older adults (Langguth et al., 2023). However, tinnitus is increasingly documented among younger adults, particularly those in high-noise occupational environments and those experiencing noise-induced hearing loss through recreational exposure (Lasisi et al., 2010; Wu et al., 2018). The theoretical framework underpinning this study integrates the Theory of Consumption Values (TCV; Ali et al., 2019), Social Choice Theory (Sen, 1991), Desire Theory (Lin, 2022), and Subjective Well-Being Theory (Casino-García et al., 2019), predicting that adoption decisions are multidimensional and cannot be reduced to demographic predictors alone.

II. METHOD

Research Design

This study adopted a convergent parallel mixed-methods design (Creswell & Creswell, 2018), integrating three concurrent strands: sentiment analysis of app store reviews, a cross-sectional online survey, and in-depth semi-structured interviews. A pragmatic epistemological stance was adopted

(Fetters & Molina-Azorin, 2019), alongside an abductive reasoning strategy (Saunders et al., 2016).

Strand 1: Sentiment Analysis

A systematic search of the Google Play Store and Apple App Store was conducted using Appbot. The keyword ‘tinnitus’ retrieved an initial pool of 77 applications. After applying inclusion criteria (availability on both platforms, minimum five reviews, reviews submitted July-December 2022), 42 applications were retained, yielding 13,096 user reviews. Appbot’s natural language processing algorithms classified each review as positive, negative, neutral, or mixed. Python libraries (Pandas, NumPy, Matplotlib, Gensim) were used for data aggregation and visualisation (Sereda et al., 2019).

Strand 2: Cross-Sectional Survey

An online survey was distributed between March and June 2024 to adults with self-reported tinnitus through tinnitus support associations, closed social media communities (combined membership approximately 10,000), and medical facility registries in the United Kingdom and Nigeria. Sample size was estimated using Yamane’s formula (population $N = 13,095$; 5% margin of error; target $n = 388$); 171 usable responses were received. The instrument assessed socio-demographic characteristics, tinnitus history, app adoption, feature usefulness, health content evaluation, security perceptions, usability, and subjective well-being. Inferential statistics included chi-square tests of independence and point-biserial correlation, computed manually and cross-verified in Microsoft Excel (Pallant, 2011; Portney, 2020).

Strand 3: Semi-Structured Interviews

Nineteen participants were purposively selected from survey respondents to maximise diversity in age, gender, tinnitus severity, occupation, and app engagement level. The sample additionally included a professional audiologist, an ENT consultant, and a tinnitus app developer. Interviews lasted 30-45 minutes and were conducted face-to-face or online. Sessions were audio-recorded, transcribed using NVivo, and verified manually. Thematic analysis was conducted following Braun and Clarke’s framework (Creswell & Poth, 2018).

Ethical Approval

Ethical approval was granted by the Northumbria University Faculty of Engineering and Environment Ethics Committee. All participants provided written informed consent. Data were anonymised and stored on encrypted university servers.

III. RESULTS

Socio-Demographic Profile

Table 1 presents the demographic characteristics of the 171 survey respondents. The sample was predominantly female (66.3%) and skewed towards older age groups, with 44.8% aged 60-79 years (Figure 2).

Table 1. Socio-Demographic Characteristics of Survey Participants ($N = 171$).

Variable	Category	n	%
Gender	Female	113	66.3
	Male	53	30.7
	Other / Prefer not to say	5	2.9
Age (years)	18-29	6	3.7
	30-49	45	26.4
	50-59	40	23.3
	60-79	77	44.8
	80+	3	1.8
Employment Status	Full-time employed	71	41.7
	Retired	53	30.7
	Part-time / Other	47	27.6
Tinnitus Location	Both ears	119	69.3
	Left ear only	28	16.6
	Right ear only	24	14.1
Duration of Symptoms	< 5 years	56	32.5
	5-14 years	67	39.3
	15 or more years	48	28.2
App Adoption	Yes (active users)	19	8.6
	No (non-users)	152	91.4

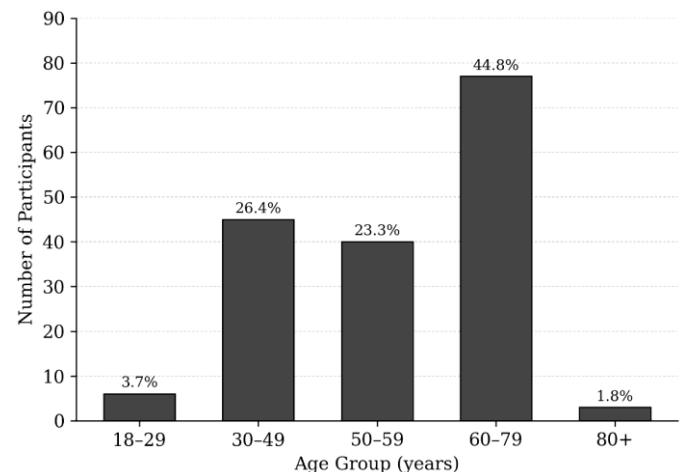


Figure 2. Age distribution of survey participants ($N = 171$).

However, 26.4% were aged 30-49 and 3.7% were aged 18-29. Full-time employment was the most common status (41.7%),

followed by retirement (30.7%). Tinnitus affected both ears in 69.3% of respondents, and 67.5% had experienced symptoms for five or more years. Critically, 91.4% reported never having used a tinnitus management mobile application.

The largest group was aged 60-79 years (44.8%, n = 77), though participants aged 30-49 (26.4%, n = 45) and 50-59 (23.3%, n = 40) were also substantially represented.

Non-Adoption Rate and Demographic Predictors

Table 2 presents chi-square tests of independence between app adoption and key demographic variables. No statistically significant associations were found for either age ($\chi^2 = 6.25$, df = 4, $p > .05$) or gender ($\chi^2 = 0.42$, df = 4, $p > .05$), confirming that non-adoption is not significantly predicted by these characteristics. Figure 3 illustrates the adoption distribution across age groups.

Table 2. App Adoption Cross-Tabulated with Key Demographic Variables.

Variable	Category	App Users (n)	Non-Users (n)	χ^2 (df)	p
Gender	Female	10	103	0.42 (4)	>.05
	Male	4	49		
Age (years)	18-29	1	5	6.25 (4)	>.05
	30-49	5	40		
	50-59	5	35		
	60-79	3	74		
	80+	0	3		
Employment	Full-time	7	64	—	—
	Retired	2	51		
	Part-time / Other	5	42		

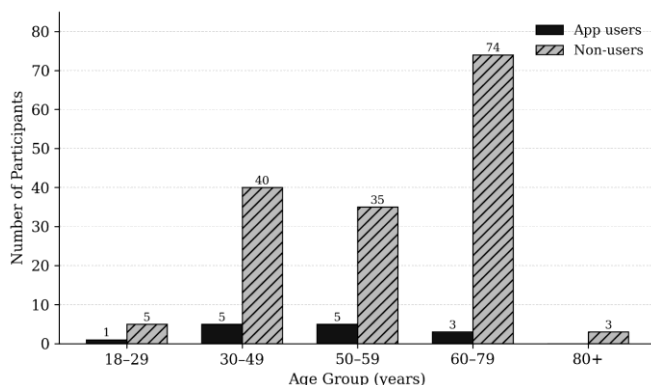


Figure 3. Mobile application adoption by age group (N = 171).

Adults aged 30-49 and 50-59 each contributed five of the 14 feature-survey-completing app users, contradicting the assumption that adoption is concentrated among older adults.

User Heterogeneity: Challenging Demographic Stereotypes

Despite the non-significant chi-square results, inspection of the cross-tabulation reveals a user profile more heterogeneous than commonly assumed. The 30-49-year age group contributed 35.7% of active app users (5 of 14), equivalent to the 50-59-year group. Full-time employed professionals constituted the largest single occupational category among adopters (7 of 14; 50%), substantially exceeding retirees (2 of 14; 14.3%). Table 3 presents the full demographic characteristics of the 19 interview participants, illustrating occupational and geographic diversity spanning the United Kingdom and Nigeria.

Table 3. Demographic Characteristics of Interview Participants (N = 19).

Participant	Age Band	Gender	Occupation	Location
1	18-25	Female	Self-employed	London
2	30-49	Male	Full-time office worker	Manchester
3	60-79	Female	Retired	Bristol
4	30-49	Non-binary	Full-time teacher	Birmingham
5	18-29	Male	Full-time (construction)	Cardiff
6	50-59	Male	Self-employed	Leeds
7	50-59	Female	Long-term illness	Liverpool
8	30-49	Male	Part-time employed	Newcastle
9	50-59	Male	Full-time (sales)	London
10	30-49	Male	App developer	Wales
11	30-49	Male	Audiologist	Wales
12	50-59	Male	ENT Consultant	Nigeria
13	50-59	Female	Full-time employed	Newcastle
14	30-49	Male	Self-employed	Nigeria
15	30-49	Female	Housewife	Nigeria
16	60-79	Male	Retired	Newcastle

17	30-49	Male	Part-time employed	Nigeria
18	60-79	Male	Retired and part-time	Leeds
19	50-59	Female	Part-time employed	Newcastle

Well-Being, Feature Usefulness, and Quality Ratings

A point-biserial correlation demonstrated a very strong positive relationship between binary app use and subjective well-being scores ($r_{pb} = 0.82$, $p < .001$). Among active app users ($n = 14$), ambient sounds (71.4% useful or very useful) and educational information about tinnitus (64.3%) were the highest-rated features. Advanced features including binaural beats (71.4% unsure), isochronic tones (64.3% unsure), and hypnosis for tinnitus (64.3% unsure) generated high rates of uncertainty, reflecting insufficient in-app educational scaffolding rather than active rejection. Figure 4 presents the full feature usefulness distribution.

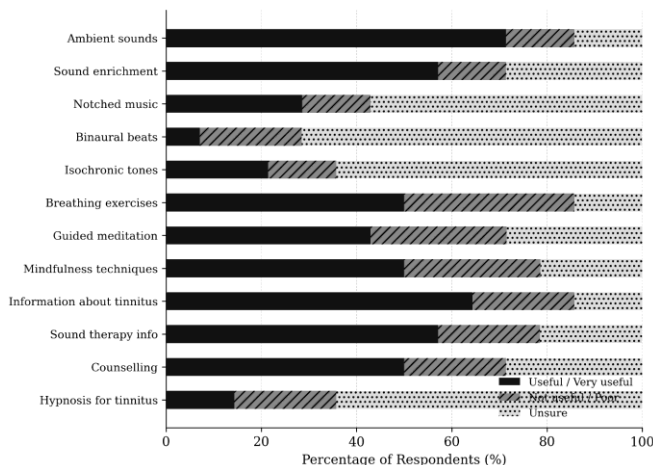


Figure 4. Feature usefulness ratings among active app users ($n = 14$).

Sound-based features (ambient sounds, sound enrichment) and educational content received the highest useful or very useful ratings. Advanced features (binaural beats, isochronic tones, hypnosis) generated substantial uncertainty, indicating a need for better in-app guidance.

Quality dimension ratings revealed consistently high importance across all domains (Table 4). Figure 5 presents a radar chart illustrating the mean importance rating profile across usability, health content, security and privacy, technical performance, and transparency dimensions.

Table 4. App Quality Dimension Ratings Among Active App Users ($n = 14$).

Quality Domain	Criterion	Important / Very Important (%)
Usability	Functionality	100.0
	Installation and setup	92.9
	Customisation / tailoring	85.7
	Ease of use (low literacy)	78.6
	Multilingual availability	71.4
Health Content	Quality of information	92.9
	Potential for harm	92.9
	Appropriate measurement	85.7
Security / Privacy	Literacy level of content	85.7
	Data protection against threats	85.7
	Data sharing transparency	85.7
	Breach notification	85.7
Technical	Anonymisation	78.6
	Software performance / stability	85.7
	Interoperability	71.4
Transparency	Accuracy of app store description	100.0
	Cost transparency	71.4
	Consent	71.4

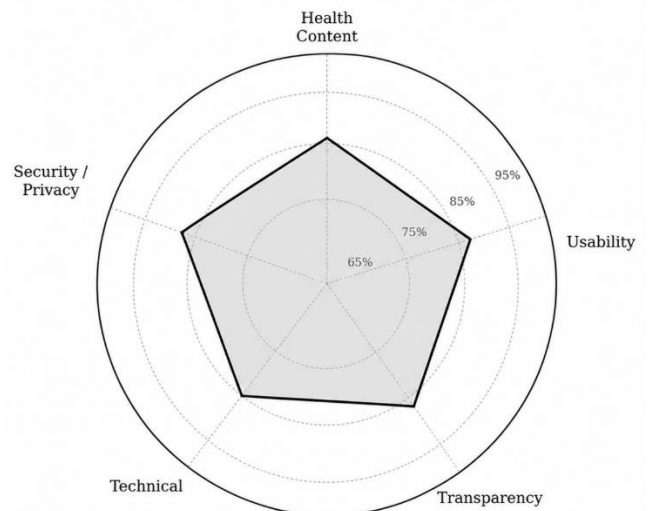


Figure 5. Mean importance ratings by quality dimension among active app users ($n = 14$).

All five domains exceeded 78% importance, with Usability and Health Content recording the highest mean ratings. Ratings are expressed as the mean percentage of respondents rating each criterion as important or very important.

Table 5 summarises the inferential statistical results. All three null hypotheses were rejected, providing quantitative confirmation that app feature quality, app use frequency, and subjective well-being are positively and significantly interrelated.

Table 5. Summary of Inferential Statistical Results.

Hypothesis	Test	Statistic	p	Decision
H ₁ : App features are not relevant to user needs	Spearman rs	rs = 0.81	<.01	Reject H ₀
H ₂ : App use does not affect management outcomes	Mann-Whitney U	U = 12.5	<.05	Reject H ₀
H ₃ : App use does not improve well-being	Point-biserial rpb	rpb = 0.82	<.001	Reject H ₀

Barriers to Adoption: Qualitative Themes

Theme 1: Low awareness and absent clinician referral pathways.

The most pervasive barrier was low awareness of the existence of tinnitus-specific applications. No participant with tinnitus reported receiving a clinician recommendation for a mobile app; discovery occurred primarily through online support communities. One participant stated:

"I had no idea these apps existed until I joined an online tinnitus forum. My audiologist never mentioned them." (Participant 7, Female, Liverpool)

The audiologist interviewed (Participant 11) confirmed that apps were not yet part of standard clinical practice, despite acknowledged therapeutic potential. Figures 6 and 7 present the top negative and positive sentiment topics from the review analysis, providing quantitative context for this qualitative finding.

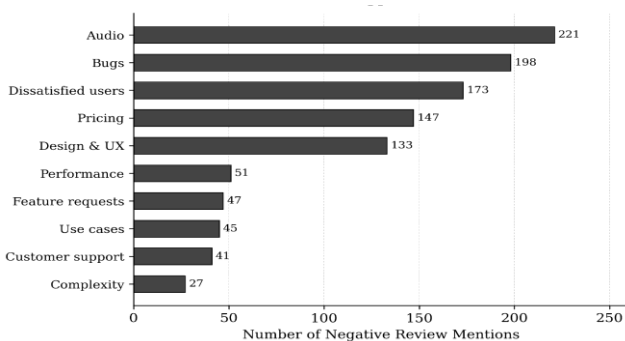


Figure 6. Top 10 negative discussion topics across all tinnitus app reviews (n = 13,096).

Audio issues (n = 221), Bugs (n = 198), and Dissatisfied users (n = 173) were the most frequently cited negative themes, reflecting marketplace quality inconsistency.

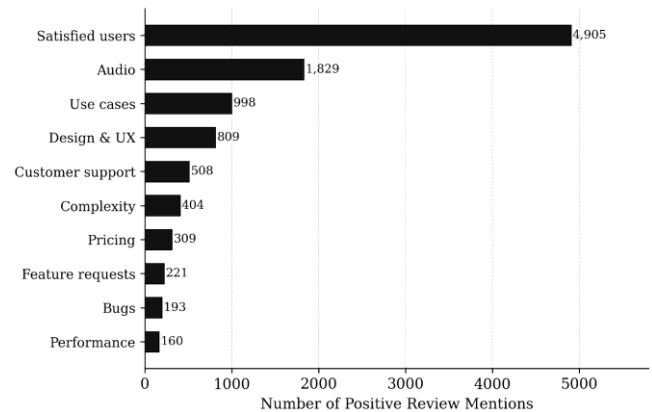


Figure 7. Top 10 positive discussion topics across all tinnitus app reviews (n = 13,096).

Satisfied users (n = 4,905) dominated positive sentiment, followed by Audio (n = 1,829) and Use cases (n = 998), confirming strong utility among adopters.

Theme 2: Lack of standardisation and quality uncertainty.

Participants described difficulty distinguishing evidence-based applications from lower-quality alternatives in an unregulated marketplace. The ENT consultant (Participant 12) expressed reluctance to recommend apps without clinical-grade certification. The app developer (Participant 10) advocated for a visible clinically endorsed quality badge to differentiate trustworthy apps, stating it would "immediately separate us from the noise."

Theme 3: Limited personalisation and feature mismatch.

Participants who had discontinued app use cited mismatches between their symptom profile and generic content. Participant 8 noted that sounds were not tailored to their specific tinnitus frequency. Participant 9 described the need for different settings in each ear for bilateral tinnitus, functionality absent from most apps. High uncertainty ratings for advanced features (Table 4; Figure 4) reflected insufficient in-app guidance rather than user rejection.

Theme 4: Digital literacy and onboarding complexity.

Participants aged 60 and above described challenges with initial installation and navigation. Participant 18 (Male, Leeds) noted that family assistance was required for setup. Sentiment analysis corroborated this: the 'Complexity' topic generated 466 review mentions, with successful complexity management

a strong driver of positive sentiment and failures generating frustration. Among active app users, ease of use for low-literacy users was rated important or very important by 78.6%, and multilingual availability by 71.4%.

Theme 5: Privacy, data security, and trust.

Privacy concerns were expressed across all participant groups, with particular intensity among Nigerian participants where awareness of data governance frameworks was lower. Participant 14 (Male, Nigeria) stated uncertainty about who could access health data was a direct barrier to adoption. Survey data confirmed data sharing transparency (85.7%) and breach notification (85.7%) were among the highest-rated quality criteria.

suggesting that tinnitus apps face particularly severe structural barriers. Chi-square testing confirmed that neither age nor gender significantly predicted adoption ($p > .05$ for both), indicating that barriers are systemic rather than tied to specific demographic groups.

This finding directly contradicts the assumption that low adoption reflects the predominantly older age profile of tinnitus patients and associated digital literacy deficits. Rather, the barriers identified, absent clinician referral pathways, marketplace quality uncertainty, limited personalisation, onboarding complexity, and privacy concerns, apply across demographic groups and therefore require systemic rather than demographically targeted solutions (see Figure 8).

Challenging Demographic Stereotypes

Adults aged 30-49 constituted 35.7% of active app users, and full-time employed professionals constituted 50%, the largest single occupational category among adopters. This aligns with emerging epidemiological evidence of tinnitus among younger adults in high-noise occupational and recreational environments (Lasisi et al., 2010; Wu et al., 2018), and with broader digital health literature suggesting working-age adults engage with health apps when they perceive clear personal relevance (Chakraborty & Paul, 2023). The interviews further revealed that younger professionals used apps in work-related contexts, commutes, lunch breaks, that differ substantially from the bedtime use typical of retired adopters, demanding context-adaptive design.

The inclusion of Nigerian participants extended the demographic scope and revealed that adoption barriers are not uniform: Nigerian participants faced additional structural challenges related to data trust, cost, and internet connectivity. Inclusive design must therefore account for infrastructural and institutional variation across healthcare systems.

Systemic Barriers and Recommendations for Practice

The awareness barrier is the most tractable: systematic clinician recommendation, supported by evidence-based app selection guides analogous to those developed for mental health (Beukes et al., 2022), could dramatically increase adoption without requiring changes to app design. The audiologist and ENT consultant interviewed both confirmed app recommendation was not part of current practice, a gap that targeted continuing professional development could address rapidly.

The quality standardisation barrier requires structural change. Mehdi et al. (2020a) called for standardised quality frameworks embedded within app store certification. Deshpande and

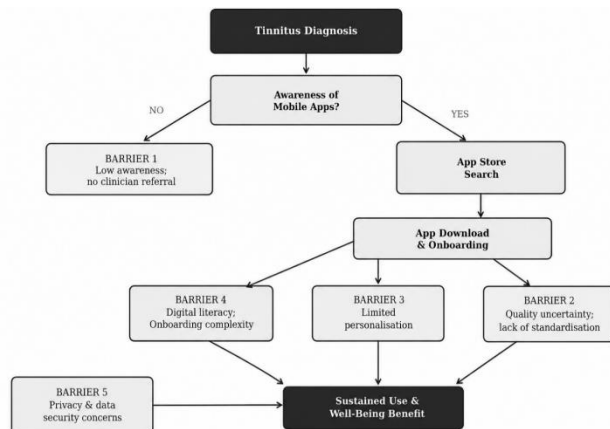


Figure 8. Conceptual framework of barriers to mobile tinnitus app adoption across diverse populations.

The framework illustrates the decision pathway from tinnitus diagnosis through awareness, app search, download, and onboarding to sustained app use and well-being benefit, while highlighting five key barriers that may impede progression at different stages: low awareness, quality uncertainty, limited personalisation, digital literacy, and privacy and data security concerns.

IV. DISCUSSION

The Non-Adoption Paradox

The central finding of this study is one of significant paradox: tinnitus management apps demonstrate strong therapeutic benefit for those who adopt them ($rpb = 0.82$, $p < .001$), yet 91.4% of tinnitus patients surveyed had never used one. The magnitude of this non-adoption rate exceeds typical mHealth non-adoption figures (Rakshit et al., 2021; Vahdat et al., 2021),

Shimunova (2019) advocated clinical review panels. The app developer interviewed supported a clinically endorsed quality badge system. The personalisation barrier requires adaptive onboarding and progressive feature disclosure. High uncertainty for advanced features (Figure 4) reflects navigational confusion rather than user rejection, a design problem that symptom-profiling onboarding could resolve.

Five evidence-based design principles emerge for tinnitus apps targeting diverse populations:

- Adaptive onboarding: symptom profiling at first launch to match therapeutic features to individual profiles.
- Progressive disclosure: educational scaffolding contextualising advanced features within evidence-based explanations.
- Multilingual interfaces: rated important or very important by 71.4% of active users; a functional requirement, not a premium feature.
- Simplified security communication: prominent plain-language trust indicators at installation to replace lengthy privacy policies.
- WCAG 2.1 Level AA accessibility compliance: screen reader compatibility, colour contrast, and adjustable font size as baseline requirements.

Comparison with Prior Literature

The finding that clinician recommendation is a primary determinant of mHealth adoption aligns with Henry et al. (2017), who demonstrated that audiologist endorsement significantly increased tinnitus app uptake. The identification of privacy concerns as a significant barrier is consistent with Abowd and Schmutte (2019). The demographic heterogeneity finding extends Manchaiah et al. (2022), who documented diverse tinnitus patient profiles in online support communities. The present study provides, for the first time, direct quantitative evidence that neither age nor gender significantly predicts adoption, while simultaneously demonstrating that adoption is strongly associated with well-being: a combination with critical policy implications, because it means that all demographic groups are equally reachable, and reaching them would deliver meaningful clinical benefit.

Limitations

Several limitations should be noted. First, the achieved survey sample ($N = 171$) fell short of the Yamane-calculated target ($n = 388$), limiting statistical power. Second, self-reported non-adoption may be subject to recall bias. Third, the cross-sectional design precludes causal inference: the correlation between app use and well-being ($r_{pb} = 0.82$) cannot establish directionality. Fourth, the sample was predominantly recruited

through English-language online communities, potentially excluding individuals with lower educational attainment or limited English proficiency. Fifth, non-adopters were not specifically recruited for in-depth interview, limiting qualitative explanation of non-adoption motivations. Longitudinal and experimental designs are required to address these limitations.

V. CONCLUSIONS

This study presents comprehensive mixed-methods evidence that 91.4% of tinnitus patients do not use mobile management apps, not because of who they are demographically, but because of systemic failures in the app ecosystem. The user base is more demographically diverse than assumed: younger professionals in full-time roles are a significant and largely overlooked group. Five systemic barriers explain the paradox of high efficacy among adopters and near-total non-adoption in the broader population. Closing this gap requires coordinated action by app developers (inclusive, adaptive design), clinicians (systematic recommendation), and policymakers (quality certification and public awareness campaigns). When these conditions are met, tinnitus management mobile applications have the potential to deliver demonstrated therapeutic benefits to millions of individuals for whom they currently remain inaccessible.

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Declaration of Interest

The authors report no conflict of interest.

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