Original Research

DIGITAL HEALTH

Digital Health
Volume 8: 1–9

DOI: 10.1177/20552076221113204
journals.sagepub.com/home/dhj
SAGE

# Global use and outcomes of the hearWHO mHealth hearing test

**Karina C De Sousa[1,2], Cas Smits[3], David R Moore[4,5], Shelly Chada[6], Herman Myburgh[7] and De Wet Swanepoel[1,2,8]**

## Abstract

**Objectives:** The objective of this study was to examine the uptake, user characteristics, and performance of the free WHO smartphone hearing screening test (*hearWHO*) as a global hearing health promotion initiative.

**Method:** We retrospectively examined the data of 242 626 tests conducted by adults (> 18 years) on the *hearWHO* app between February 2019 and May 2021. Test uptake was evaluated by country, WHO world region, test date, and demographics of age and gender.

**Results:** The *hearWHO* test was completed in nearly every country globally ($n = 179/195$), with the greatest uptake seen in China and India. Uptake was greatest in the Western Pacific (32.9%) and European (24.8%) WHO regions. There was a high uptake of tests (44%) by young adults under the age of 30 years. Referral rates were typically higher for older age groups in most WHO regions, except for the African and Eastern Mediterranean regions, where overall *hearWHO* test uptake was lowest. Most testing (49%) took place in March (2019–2021) coinciding with World Hearing Day (3rd of March) each year.

**Conclusions:** Digital mhealth tools provide many benefits in healthcare, including health promotion, access to information, and services for hearing loss. The *hearWHO* test was mainly reaching younger adults, positioning it as an important measure for public health advocacy to prevent hearing loss. Since hearing loss is primarily age related, more targeted campaigns or community-based initiatives should be directed toward older adults.

## Keywords

Public health disease, digital health general, eHealth general, internet general, smartphone media, apps personalized medicine, connected care personalized medicine, self-efficacy personalized medicine, mHealth psychology

Submission date: 22 June 2021; Acceptance date: 23 June 2022

[1]Department of Speech-Language Pathology and Audiology, University of Pretoria, Pretoria, South Africa
[2]Virtual Hearing Lab, Collaborative initiative between the University of Colorado and the University of Pretoria, Aurora, Colorado, USA
[3]Amsterdam UMC location University of Amsterdam, Otolaryngology-Head and Neck Surgery, Ear and Hearing, Amsterdam Public Health research institute, Amsterdam, The Netherlands
[4]Communication Sciences Research Center, Cincinnati Childrens' Hospital Medical Center and University of Cincinnati, Cincinnati, OH, USA
[5]Manchester Centre for Audiology and Deafness, University of Manchester, Manchester, UK
[6]Department of Noncommunicable Diseases, World Health Organization, Geneva, Switzerland
[7]Department of Electrical, Electronic and Computer Engineering, University of Pretoria, Pretoria, South Africa
[8]Ear Sciences Centre, School of Surgery, University of Western Australia, Nedlands, Australia

**Corresponding author:**
De Wet Swanepoel, Department of Speech Language Pathology and Audiology, University of Pretoria, c/o Lynnwood & Roper Street, Pretoria, South Africa.
Email: dewet.swanepoel@up.ac.za

## Introduction

Throughout the life course, hearing loss has pervasive effects. Besides the detriment to early childhood development,[1] it is associated with factors central to the quality of life in adults, including increased risk of depression, loneliness,[2] unemployment,[3] and dementia.[4] Conservative estimates indicate that by 2050, nearly 1 in 4 people will have a certain degree of hearing loss and, for 1 in 14 people, it will be of a moderate or higher degree.[5] There has been a drive to address hearing loss, leading to the report on the *Global cost of unaddressed hearing loss and cost-effectiveness of interventions* by the World Health Organization (WHO) in 2017,[6] the *Resolution and action plan for prevention of deafness and hearing loss* at the World Health Assembly in 2017[7] and, most recently, the *World Report on Hearing* in 2021.[5] The World Report calls for urgent investment in hearing loss prevention, considering that, in 2020, nearly 1 trillion international dollars was lost globally due to unaddressed hearing loss.[8]

Lack of awareness and knowledge by the public and health care providers has contributed to insufficient prevention, early detection and treatment of hearing loss, with stigmatization largely unaddressed. Almost one billion young adults are at risk of preventable hearing loss due to unsafe listening practices.[5] Hearing promotion through screening is a strategy to promote awareness, early detection, and timely treatment. Economic benefits of reducing the prevalence and severity of hearing loss show that a 5% reduction in prevalence could reduce the global monetary loss of hearing loss by, conservatively, around 50 billion dollars per annum.[8] The World Report on Hearing (2021) has recommended the use of innovative screening measures and telehealth to make hearing care more accessible.[5]

Screening for hearing loss has been out of reach for most people with disabling hearing loss since more than 80% reside in low-and middle-income countries (LMICs) where ear and hearing care is often unavailable or limited.[5] This is due to the dearth of professionals, infrastructure, and resources to provide services.[9] While this issue is challenging in LMICs, particularly for rural communities, it is also encountered in high-income countries where nearly three-quarters of people who could benefit from hearing aids do not have them.[5,10] Utilizing digital platforms including mHealth tools is a scalable way to improve public awareness and access to hearing care. By the end of 2019, global mobile internet usage increased to 3.8 billion people, an increase of 250 million people in a single year, of which 90% were new users from LMICs.[11] As a result there has been a rapid increase in mHealth solutions for hearing loss in the past 10 years,[12] particularly for hearing screening.[13] One of the most widely used mHealth tools for hearing screening is the smartphone digits-in-noise test (DIN) that has become freely available to the general public as a self-screen for hearing loss.[12,14] On World Hearing Day 2019, WHO released an English version of the DIN test called *hearWHO*, followed by Spanish and Mandarin versions in 2021.

The DIN measures a person's ability to understand speech in noise by presenting spoken digit triplets (e.g. 3-4-7) in adaptive levels of background masking noise.[15,16] The test tracks the level where 50% of triplets could be recognized, called the speech recognition threshold (SRT).[14] The *hearWHO* app uses an antiphasic test paradigm, where the target speech is presented binaurally out-of-phase.[17] The antiphasic SRT has high sensitivity and specificity of more than 80% to detect different types of hearing loss and correlates strongly with clinical pure tone audiometry performed in sound-treated environments.[17,18] Unlike traditional pure tone audiometry, which requires a trained test facilitator, calibrated equipment and soundproof booth, the test can be accurately conducted on many devices without device calibration. Groups of three successive digits are easily understood, remembered, and entered on a keypad, making it an undemanding task in terms of language and cognition. In addition, self-testing makes for a versatile, accurate, and rapid (3 min) screen.

Healthcare developments in mHealth like the *hearWHO* app are affordable and particularly suitable for hard-to-access communities. In addition to impaired communication, unaddressed hearing loss has a high general health cost, such as the increased risk of dementia, for which hearing loss treatment is the number one modifiable risk factor.[4] The *hearWHO* app is focused on raising awareness and motivating earlier rehabilitation steps in part to prevent a cascade of neurological and mental health problems. Furthermore, digital health tools allows unique prospects to promote positive health-related lifestyle alterations.[19]

*hearWHO* has been widely used and promoted by global health organizations, governments, and hearing health organizations. This paper reports *hearWHO* hearing screening uptake across world regions, user characteristics, and performance as a mHealth hearing health promotion tool.

## Method

This study received ethical approval from the University of Pretoria Humanities Research Ethics Committee (Protocol Number: HUM025/0621).

### Participants

We retrospectively examined the data of 259,894 tests conducted on the *hearWHO* app between February 2019 and May 2021. We excluded the data of 88 tests where either the birth date, digit language, or stimulus type was captured in an incorrect format rendering the data unavailable (technical issue). In addition, data of test users who indicated age under 18 years ($n = 17{,}180$) were excluded from the

analyses, as the test validation and cut-offs are currently based on adult normative data. There was a small group of test users ($n = 56$) who indicated age over 100 years that were kept in the analyses. Furthermore, 0.9% ($n = 2192$) of users reached a ceiling SRT test (17.7 dB SNR) possibly reflecting an unreliable test but their data were kept in the analyses to indicate actual test performance across test users. The *hearWHO* test was completed by downloading the application on an Android ($n = 137{,}479$) or iOS ($n = 105{,}147$) device. We did not include tests from the *hearWHO Pro* test version, used by health workers to screen people in their communities. Before completing the test, users were prompted to choose their preferred test language between English ($n = 237\ 417$), Mandarin ($n = 3806$), or Spanish ($n = 1403$). The Spanish and Mandarin versions were only released on the 3rd of March 2021, two years after the initial launch, with English as the only test option.

### Procedures

Before the test, users were asked to select their birth year and native language and whether the test was completed as a self-test or with the help of a test facilitator. Thereafter, participants were instructed to connect headphones and select a comfortable volume while digit-triplets were presented without masking noise. Afterwards, 23 digit-triplets (e.g. 3-5-8) were randomly selected and presented using an antiphasic paradigm, where the digits had a 180° phase shift between the ears while keeping stationary masking noise in phase.[18] The antiphasic DIN has greater sensitivity to various hearing loss types than the original diotic DIN, including bilateral or unilateral sensorineural hearing loss and conductive hearing loss.[17] The exact construction of the masking noise and test procedure can be found in De Sousa et al. (2020). The SRT was categorized, based on cut-offs, as either "Good," "OK," or "Needs Help." For the English language set, the cut-points for "Good" was set as SRTs $\leq -15.2$ dB SNR, between $-15.1$ and $-12.5$ dB SNR for "OK" hearing and $> -12.5$ dB SNR for "Needs Help," which was based on the normative dataset presented in De Sousa et al. (2020).[17]

## Results

The mean age of users was 35.7 years (SD = 14.6 years). Most of the users conducted the test themselves (87.8%, $n = 213{,}097$), and the rest with the help of a facilitator (12.2%, $n = 29{,}529$). Most tests (51.3%) were conducted in the user's non-native language. Mean SRTs were comparable between native ($-17.1$ dB SNR) and non-native ($-17.0$ dB SNR) users who passed the English version ($n = 106{,}689$).

Across all WHO regions, test uptake was highest for younger adults between the ages of 18–30 years (44.4%; Figure 1(A)). Test users under 30 years of age, who had "Good" hearing, had median SRTs of $-17.8$ dB SNR with interquartile range of 1.8 dB SNR, which was slightly better than the normative cut-point for the test. Referral rates were typically higher for older age groups in most WHO regions, except for the African and Eastern Mediterranean regions, where overall hearWHO test uptake was lowest and referral rate across age groups more even, notably in Africa (Figure 1(B)). The majority of tests globally were taken by males (56.7%; Figure 1(C)), except in the Americas WHO region (Table 1). Age-related deterioration in SRTs was evident for both females and males (Figure 2). In general, there were increasing percentages of tests in the "Needs help" hearing status category with each advancing age group (Figure 1(D)).

The *hearWHO* test was completed in nearly every country globally ($n = 179/195$; Figure 3), with the greatest uptake seen in the Western Pacific (32.9%) and European regions (24.8%; Table 1; Figure 3). Test uptake per 100,000 people showed the highest uptake in Saint Lucia, Iceland, and Ireland (Figure 4A), while overall, the greatest number of tests were conducted in China, India, and the United States (Figure 4B). Nearly half of all tests (49%) took place in March (2019–2021), coinciding with World Hearing Day held on the 3rd of March each year (Figure 5). Most of these tests were taken in 2019, and the overall rate of testing declined markedly in 2020, and again in 2021.

## Discussion

The *hearWHO* app was released as a global public health initiative to increase hearing health awareness and prevention through access to a free self-test for hearing screening. Digital mHealth technologies like *hearWHO* are becoming increasingly valuable as the world transitions into the information age, concomitant with the rapidly advancing ownership of mobile devices and internet connectivity.[11] To date, more than 250,000 *hearWHO* tests have been completed across the globe, most of which were completed in the Western Pacific and European Regions. Hearing loss prevalence is driven mainly by demographic changes and population ageing. In the coming years, the prevalence is predicted to rise in accordance with the population profile, of which the highest number of people in 2050 is expected to be in the Western Pacific.

Fewer tests were conducted in African and Eastern Mediterranean than in other regions. Unfortunately, rates of hearing loss are expected to double in these regions by 2050.[5] Several factors could have contributed to the lower uptake. For instance, Sub-Saharan Africa had a notably lower smartphone adoption rate by the end of 2020 compared to other world regions.[20] Furthermore, health promotion initiatives in sub-Saharan Africa are sorely lacking,

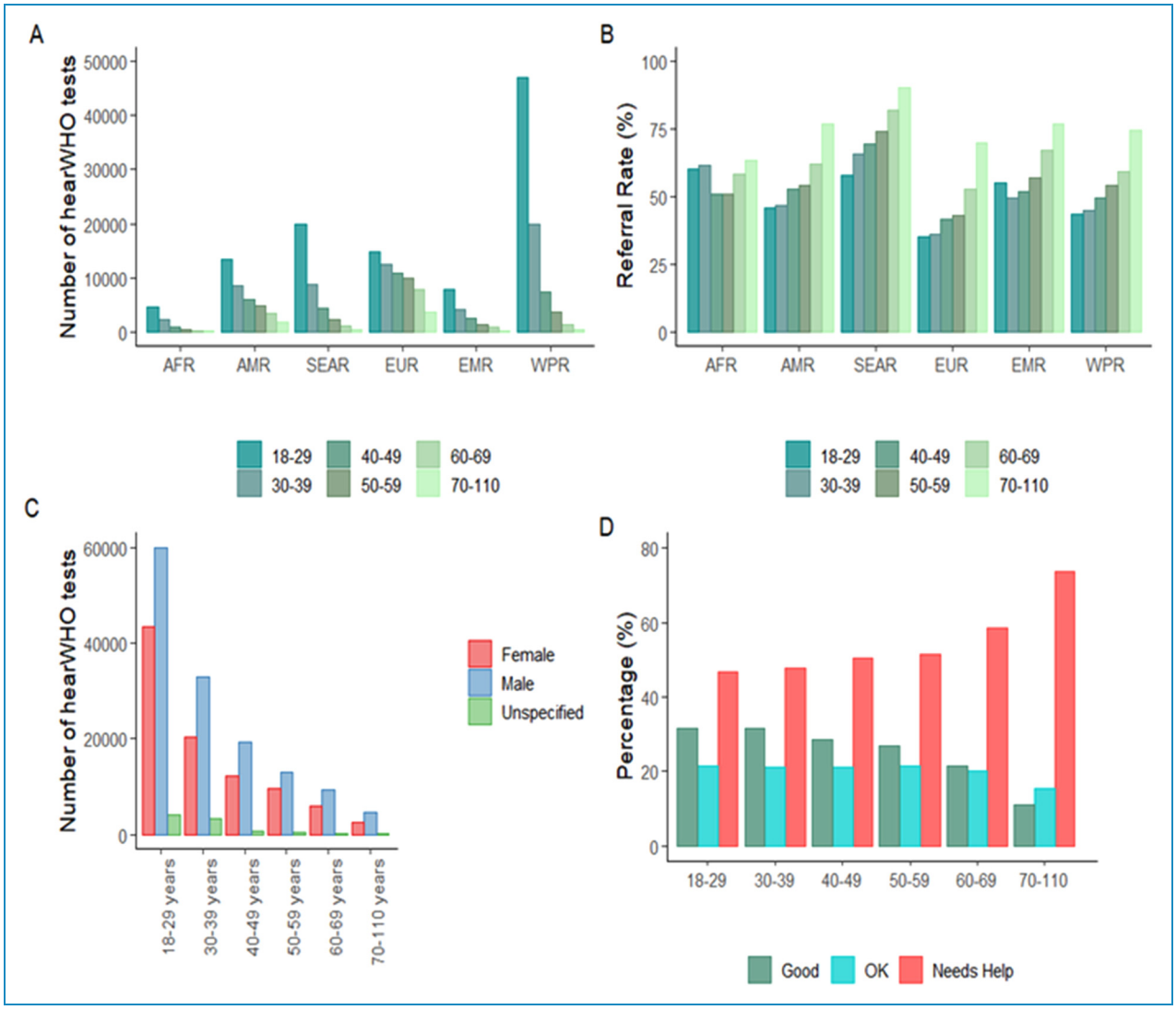


**Figure 1.** hearWHO tests according to age group and WHO region taken between February 2019 and May 2021 ($n = 242\,234$). (A) Number of hearWHO tests taken per WHO region and age group, (B) referral rate per WHO region and age group, (C) distribution of hearWHO tests across age groups between February 2019 and May 2021 ($n = 242{,}626$), (D) percentage of tests in each WHO results category according to age group.
AFR: African Region; AMR: Region of the Americas; SEAR: South-East Asian Region; EUR: European Region; EMR: Eastern Mediterranean Region; WPR: Western Pacific Region.

considering the population's generally low-health status.[21] As shown in Figure 5, health campaigns like World Hearing Day play a significant role in public awareness of available tools like the *hearWHO* app. Promotion efforts may be hampered in these regions due to a lack of adequate resources and knowledge among healthcare providers who play an important role in hearing health awareness.[5] While the DIN is not a linguistically or cognitively demanding task, test uptake is very likely influenced by the test language offered. Currently, the *hearWHO* app is only available in English, Spanish, and Mandarin. Releasing the test in other languages more widely spoken in the Eastern Mediterranean and African regions could improve the uptake and test accuracy, as the performance of the DIN in a non-native language is known to be slightly lower than for native speakers.[22] Other language versions for the *hearWHO* app are currently under development.

Younger users under 30 years were a large proportion (44%) of all tests taken. Generally, hearing loss prevalence is higher among older adults due to age-related hearing degeneration.[5] The Global Burden of Disease study in 2019 indicated that 65% of adults over 60 years have hearing loss, of which 25% are moderate or higher degrees.[23] Another example is the analyses of the UK Biobank, which showed that the ability to hear speech in background noise, measured using the digits-in-noise,

**Table 1.** hearWHO test user (18 years of age and above) characteristics and referral rates across WHO regions ($n = 242{,}234$).

| | African Region (AFR) | Region of the Americas (AMR) | South-East Asian Region (SEAR) | European Region (EUR) | Eastern Mediterranean Region (EMR) | Western Pacific Region (WPR) | Global |
|---|---|---|---|---|---|---|---|
| Tests taken *n* % | 9 218<br>3.8% | 38 562<br>15.9% | 37 256<br>15.4% | 60 091<br>24.8% | 17 317<br>7.1% | 79 790<br>32.9% | 242 234<br>100% |
| Age in years *Mean (IQR)* | 33.0 (14) | 39.4 (25) | 32.3 (15) | 43.4 (26) | 34.3 (20) | 30.4 (11) | 35.7 (20) |
| Gender | | | | | | | |
| *Male % n* | 61.0<br>5 622 | 45.8<br>17 648 | 67.3<br>25 088 | 56.3<br>33 815 | 58.6<br>10 141 | 59. 1<br>47 170 | 57.6<br>139 484 |
| *Female % n* | 35.9<br>3 307 | 51.4<br>19 805 | 29.7<br>11 080 | 41.0<br>24 648 | 37.6<br>6 504 | 35.9<br>28 647 | 38.8<br>93 991 |
| *Unspec % n* | 3.1<br>289 | 2.9<br>1 109 | 2.9<br>1 088 | 2.7<br>1 628 | 3.9<br>672 | 5.0<br>3 973 | 3.6<br>8 759 |
| Median SRT in dB SNR (IQR) | −13.4 (6.4) | −14.2 (6) | −13 (6) | −15 (5.2) | −13.8 (5.8) | −14.8 (5.6) | −14.4 (6) |
| hearWHO result category | | | | | | | |
| *Good %* | 23.3 | 28.6 | 17.0 | 35.7 | 23.0 | 33.1 | 29.5 |
| *OK %* | 17.7 | 20.2 | 19.7 | 22.0 | 22.4 | 21.6 | 21.1 |
| *Needs Help %* | 59.0 | 51.2 | 63.2 | 42.3 | 54.6 | 45.3 | 49.4 |

For 392 users the IP country address could not be identified.

declines exponentially from the age of 50 years and is linked with declining cognitive processing ability.[24] In general, age-related decline in this study was evident (Figure 2) and was in close parallel between women and men.

The overall referral rate for the *hearWHO* test was 49.4%, and, as expected, referral rates increased for each advancing age group. However, the number of users failing the test was high across all ages, even for the younger cohort under 30 years (46.8%; Figure 1D). It is possible that many users were already concerned about their hearing and subsequently took the test. Similarly, referral rates were high for a DIN released over landline and cell phone in the United States, with a reported 81% referral rate.[25] A noteworthy number of tests in the Western Pacific ($n = 46{,}884$) were taken by younger adults. Since hearing loss in the Western Pacific is estimated to rise in the coming years, it can be considered beneficial that the *hearWHO* test is promoting awareness among an important younger demographic in this region. Reaching a younger population is an effective preventative strategy to ensure hearing health awareness among the youth. However, alternative strategies should be explored to reach the critical target population of people over 60 years.

Although there has been tremendous growth in smartphone and mobile internet usage, even among LMICs and previously marginalized groups, it is recognized that there is a so-called "digital divide" among different populations, genders, age groups, and countries, which likely influences the uptake of the *hearWHO* test. In general, smartphone ownership and digital literacy are lower among older adults,[26,27] which could partially account for the lower test uptake in people over 60 years. Another probable factor is the way in which the application was promoted to the elderly. Test uptake was also greatest for males across all the age groups (Figure 1). There is a notable gender gap in smartphone ownership, especially in LMICs, with women 7% less likely to own a mobile phone and 15% less likely to use mobile internet than their male counterparts.[28] Another plausible reason for higher test uptake among males is higher hearing loss prevalence rates in men than women.[29,30] Therefore, it is

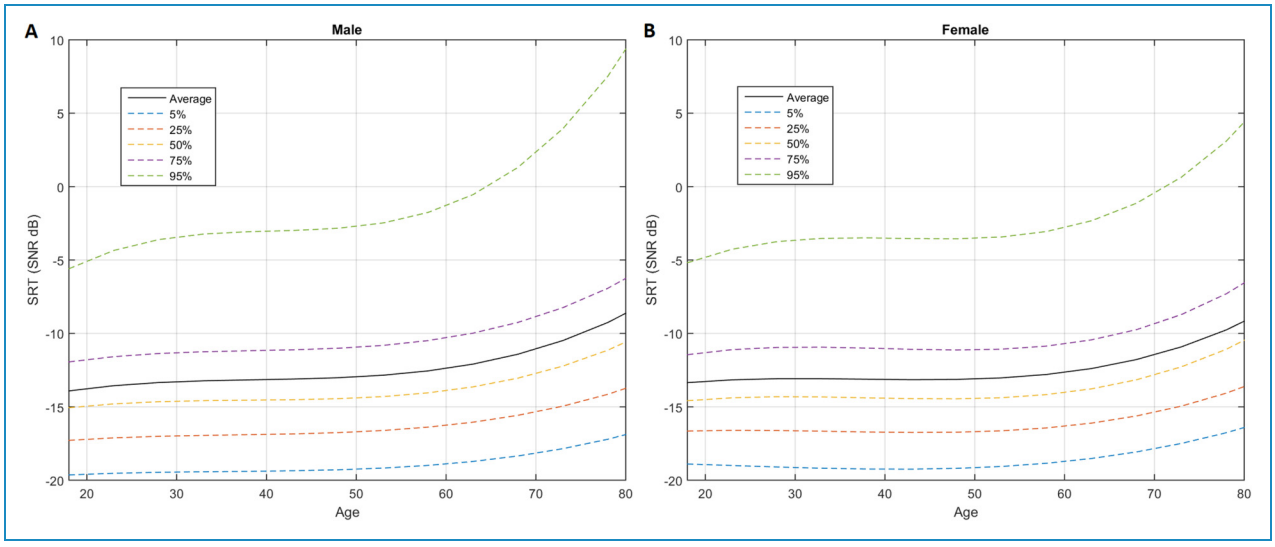


**Figure 2.** Average hearWHO DIN SRTs fitted using quantile regression across age for (A) males and (B) females ($n = 233,844$).

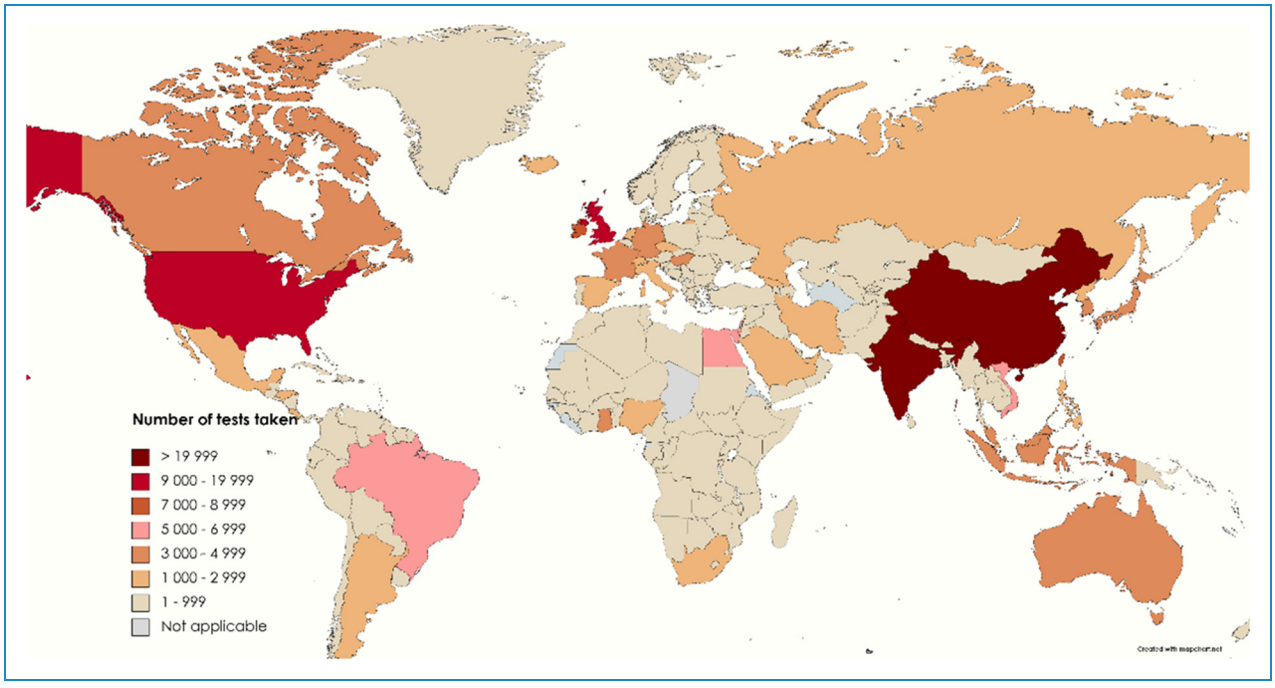


**Figure 3.** Distribution of global hearWHO tests by country between February 2019 and May 2021 ($n = 242,626$).
Not applicable means that no tests were conducted in the specific region.

possible that more males became aware of their hearing loss and subsequently completed the test.

Although the test is recommended and validated for adults, many tests ($n = 17,180$) were completed by people under 18 years, showing an interest in tools to screen younger children and adolescents' hearing. The DIN can reliably be conducted in children as young as four years old,[31] but may benefit from the help of an adult to facilitate the test.[31,32] Furthermore, speech recognition in noise is a skill that matures with age.[33] For the antiphasic DIN, maturation was seen for children up to 12 years.[31,34] A future research priority could be to validate and establish normative criteria for children in each test language.

Many *hearWHO* tests were completed in 2019, coinciding with the app release and the year's theme for World Hearing Day, "Check your hearing." Furthermore, a

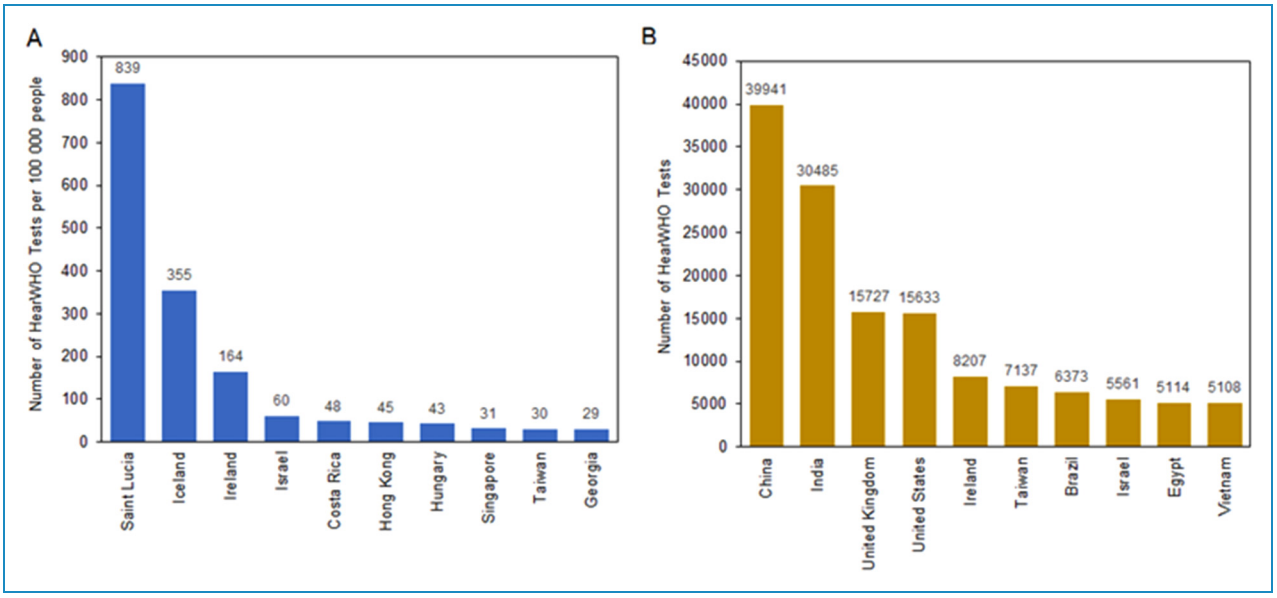


**Figure 4.** hearWHO uptake across countries. (A) Number of hearWHO tests per 100,000 people for the top 10 countries, (B) Number of hearWHO tests for the top 10 countries.

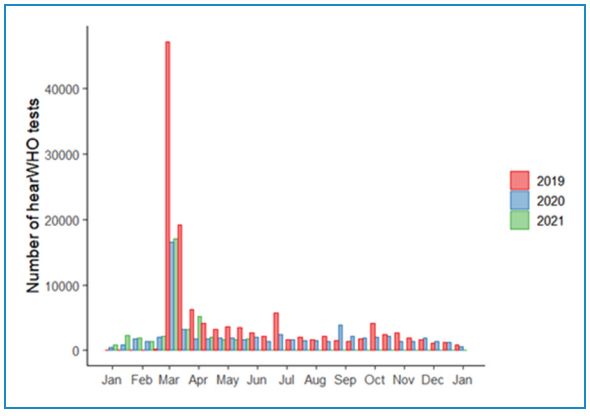


**Figure 5.** hearWHO monthly test uptake from February 2019 to May 2021 ($n = 242{,}626$).

notable spike in the number of tests seen each year in March (54.4%, 29.3%, and 55.9% of all tests for 2019, 2020, and 2021, respectively) was anticipated due to hearing loss awareness campaigns steered for World Hearing Day.[35,36] When looking at the proportion of tests with respect to population size, the best uptake was seen in Saint Lucia and Iceland, both smaller countries with an estimated population less than 400,000 people.[37] WHO activity reports indicate that Iceland launched marketing campaigns on World Hearing Day that leveraged social media, television, and radio broadcasts.[35,36] Marketing strategies are thus an effective way to increase uptake among the public, of which campaigns via digital media have proven to be valuable motivators to increase efficiency and uptake of services.[38]

mHealth tools provide many benefits in healthcare, including health promotion, access to information and services for hearing loss.[12] The *hearWHO* app is a globally utilized public health tool for raising awareness and improving access to early detection for hearing loss. Currently, the test is mainly reaching younger adults positioning it as an important measure for public health advocacy to prevent hearing loss due to unsafe listening practices.[39] Hearing loss prevalence is usually higher later in life. As such, awareness campaigns especially targeting older people using more traditional marketing campaigns like local newspapers or magazines, television or radio broadcasts may be an effective strategy. Furthermore, targeted screening programs for older adults using trained health workers and the *hearWHO Pro* screening application may be a more suitable approach. As smartphone adoption and mobile internet connectivity continue to grow across the globe, the reach of the *hearWHO* test is expected to increase. Translation in other languages and validation for people under 18 years is also likely to further improve global uptake.

**Acknowledgements:** The first author receives support from the Skye Foundation. The third author receives support from the NIHR Manchester Biomedical Research Centre.

**Contributorship:** DWS provided data. KDS, HM, and DWS analyzed the data. KDS, CS, CC, HCM, DRM, and DWS wrote and critically revised the paper.

**Conflict of interest:** DRM, HCM, and DWS have a relationship with the hearX Group (Pty) Ltd, which includes equity, consulting, and potential royalties.

**Funding:** The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Harry Oppenheimer.

**Guarantor:** KDS.

**ORCID iD:** Karina C De Sousa https://orcid.org/0000-0003-1742-1613

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