Smartphone Apps in Tinnitus

Subjects: Biotechnology & Applied Microbiology

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Smartphones containing sophisticated high-end hardware and offering high computational capabilities at extremely manageable costs have become mainstream and an integral part of users' lives. Widespread adoption of smartphone devices has encouraged the development of many smartphone applications, resulting in a well-established ecosystem, which is easily discoverable and accessible via respective marketplaces of differing mobile platforms. These smartphone applications are no longer exclusively limited to entertainment purposes but are increasingly established in the scientific and medical field. In the context of tinnitus, the ringing in the ear, these smartphone apps range from relief, management, self-help, all the way to interfacing external sensors to better understand the phenomenon. In this paper, we aim to bring forth the smartphone applications in and around tinnitus. Based on the PRISMA guidelines, we systematically analyze and investigate the current state of smartphone apps, that are directly applied in the context of tinnitus. In particular, we explore Google Scholar, CiteSeerX, Microsoft Academics, Semantic Scholar for the identification of scientific contributions. Additionally, we search and explore Google's Play and Apple's App Stores to identify relevant smartphone apps and their respective properties. This review work gives (1) an up-to-date overview of existing apps, and (2) lists and discusses scientific literature pertaining to the smartphone apps used within the context of tinnitus.

Keywords: mobile health ; smartphone apps ; tinnitus research ; biomedical and health informatics

1. Introduction

Tinnitus is a complex and heterogeneous disorder associated with causing the perception of a continuous clicking, ringing, roaring, or buzzing sound (noise) in the ears in absence of any external sound source. Approximately 15% of the world’s population suffers from tinnitus, wherein 2% of these experience a substantial decrease in quality of life due to the phantom percept [1]. Many factors associated with causing this phantom sound are still unknown, yet, it is often associated with an underlying damage in the ear, such as the loss of cochlear hair cells. The loss of the hair cells can have different origins: a common risk factor is an acoustic trauma (exposure to loud sounds), the same applies to ototoxic drugs. However, tinnitus can also develop as a symptom of a cochlear affecting disease, such as Ménière’s disease (MD), or in the course of aging and age-related hearing loss (presbycusis) [2][3]. Age-related physiologic changes, for example, degeneration of sensory receptor cells, are one common cause of disorders of the sensory systems, like the auditory system [4]. Further age-related changes have been identified in auditory processing in the brain and may be related to the generation of dementia [5][6]. Besides the increased risk of tinnitus with higher age, elder persons have also been shown to experience more tinnitus-related distress which is theorized to be related to decreased compensatory brain plasticity [7]. In a steadily aging society, presbycusis and tinnitus thus become more prevalent with consequences beyond auditory sensory handicaps.

2. Smartphone Apps in the Context of Tinnitus

Presently, tinnitus is considered as a condition that involves changes at different levels of the auditory pathway, the auditory cortex as well as non-auditory areas like the limbic system. These changes may additionally be influenced by psycho-social stress (for example, negative thoughts, the argument at home, increased workload, etc.), affecting the emotional status and the auditory system [8][9]. Consequently, variations in tinnitus loudness and tinnitus-related distress, as well as the individual perception of tinnitus has been often reported by tinnitus patients [10]. Additionally, tinnitus variations can be directly or indirectly affected by changes in the atmospheric surrounding [11] and environmental conditions of the patient [12]. Individual case studies on weather conditions and their impact on fluctuations in tinnitus show limited but some evidence of a connection [13][14]. In patients suffering from MD [15], which commonly occurs with hyperacusis [16][17], a weather change usually contributes to tinnitus increase [18]. Abrupt change in barometric pressure (particularly reduced pressure) may cause or increase tinnitus symptoms because it affects the eardrum, the round window, and the cochlear fluids. Increased wind speed or humidity also worsen the tinnitus symptoms due to influences of high sensitivity on the ears [12]. A similar relationship applies to seasonal change [19].

Smartphone-based Ecological Momentary Assessments (EMA) methods can be utilized to capture the variations in tinnitus perception and link them to current surrounding or environmental conditions of the patient [20]. Furthermore, the tinnitus variations related to stress can be coped with using smartphone-based Cognitive Behavioural Therapy (CBT) or self-help apps, and individual perception of tinnitus can be managed using smartphone-based tinnitus relief apps. Despite smartphones, smartphone apps, and auxiliary health devices, for instance, heart meters, activity trackers, and smart wristbands, have become popular in assisting patients in managing and controlling their health problems [21][22], further research to determine the effectiveness of these applications and devices in different domains of healthcare is still required [23][24]. Nonetheless, smartphones are interesting in particular as most of today's smartphones provide high computational power, a long-lasting battery life, and incorporate a set of sophisticated built-in sensors that are capable of accurately monitoring environmental surroundings and can be programmed and managed by apps. Additionally, smartphones provide an application ecosystem, extendable to program and include new apps targeting different health problems at almost negligible costs. New smartphone apps can be designed or existing apps can be tailored to assist in managing or mitigating the symptoms of different health problems [25]. For instance, mobile crowdsensing and smartphone-app solutions can be applied to monitor the ecological or environmental surroundings of patients using the built-in sensors [26][27]. Similarly, for tinnitus, these smartphone-app–based solutions also apply. However, due to the fast-growing development and the continuous publishing and inclusion of new apps in the app market places, the current state of smartphone apps within the context of tinnitus is mostly unbeknownst to patients and clinicians alike.

In this paper, based on the PRISMA guidelines [28], we explore online scientific literature sources namely: Google Scholar, CiteSeerX, Microsoft Academics, and Semantic Scholar as well as app stores, namely: Google's Play Store and Apple's App Store to list and identify tinnitus-related smartphone apps. The idea of this paper is to list and index smartphone-based solutions for assisting patients suffering from tinnitus, to foster a better understanding, management and treatment (by the provision of therapeutic solutions), as well as monitoring the severity of their tinnitus. Likewise, we report on apps that succor tinnitus patients in testing for hearing impairment (usually accompanied by tinnitus [29]), and, if possible, protect and train the remaining hearing abilities.

A review by Sereda et al. [30] lists tinnitus management apps based on patient opinions, gathered via a web-based survey. Moreover, the apps identified through a web-based patient survey are further evaluated based on the Mobile Application Ratings Scale (MARS) [31]. The added value from our review is primarily the exploration of the smartphone app markets to reveal relevant apps, as opposed to using a survey. The review by Kalle et al. [32] discusses internet- or smartphone-delivered CBT, with particular focus on self-help for tinnitus. The authors demonstrate the role of several approaches in advancing tinnitus clinical practice, but have focused less on current and available apps for patients. The review by Lui et al. [33] addresses efficacy or effectiveness of mental-health-app–based therapeutic solutions, but not with a particular focus on tinnitus. However, they do consider apps based on CBT, one of the most common therapies in the tinnitus domain. In our review, we do not limit the scope to CBT, self-help, or mindfulness apps, rather we expand further to address apps that also fall into the non-therapeutic category. In another article [34], the authors have outlined hearing healthcare apps from prominent smartphone platforms. However, the list of apps is limited and most apps have been outdated. Similarly, Bright and Pallawela [35] discuss smartphone apps for hearing assessments including comparison and validation of apps. In comparison, the scope of our proposed work is not limited to hearing assessments, but further includes additional apps for hearing healthcare, for instance, hearing protection and enhancement apps.

In summary, unlike the aforementioned studies and reviews, the objective of the presented review is to identify and report on smartphone-based solutions (apps specifically), within the context of tinnitus, that are, in turn, widely and easily available on mainstream app stores. Additionally, a further objective is to report on the current state of smartphone-based app solutions presented in the literature, be that either in the form of discussing the underlying technology or technique used for the development of the smartphone app, or the effectiveness of the smartphone apps for tinnitus patients.

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