THE RELATIONSHIP BETWEEN HEARING AND FUNCTIONAL MOBILITY AMONG OLDER ADULTS AT BASELINE IN THE CANADIAN LONGITUDINAL STUDY ON AGING

by

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Dalhousie University is located in Mi'kma'ki, the
ancestral and unceded territory of the Mi'kmaq.
We are all Treaty people.

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Abstract

Mobility problems, prevalent among older adults, are influenced by numerous factors that are interrelated. The primary purpose was to examine the relationship between hearing, measured by Pure-Tone Audiometry, and mobility, measured by Timed-Up-and-Go test, in Canadians 65–85 years of age, using the Canadian Longitudinal Study on Aging Comprehensive baseline dataset. The secondary purpose was to examine the association between mobility and hearing further in the context of other explanatory variables. Various levels of impairment in hearing and mobility were observed across the sample. According to the results of the hierarchical multiple linear regression, controlling for age and sex, hearing threshold explained 0.5% ($p<.05$) of the variation in mobility. A unique contribution of hearing threshold persisted when vision, executive function, life-space mobility, and frailty were added to the model; the total variance explained was 19.2%. This study informs future experimental work concerning the association between hearing and mobility.

List of Abbreviations Used

ADL – Activities of Daily Living

ADM – Abductor Digiti Minimi

AH – Abductor Hallucis

BB – Biceps Brachii

BMI – Body Mass Index

CAPI – Computer-Assisted Personal Interview

CCHS-HA – Community Health Survey-Healthy Aging

CLSA – Canadian Longitudinal Study on Aging

CNS – Central Nervous System

COM – Center of Mass

COP – Centre of Pressure

CR – Chair Rise

CRT – Choice Reaction Task

CRT – Choice Reaction Task

cVEMP – Cervical Vestibular Evoked Myogenic Potential

CWST – Color-Word Stroop Test

D-KEFS – Delis Kaplan Executive Function System

DCS – Data Collection Site

DGI – Dynamic Gait Index

DKEFS-TMT – Delis Kaplan Executive Function System Trail Making Test

DSC – Digital-Symbol Coding

DT – Dual-task

EDC – Extensor Digitorum Communis

EMG – Electromyography

ETDRS – Early Treatment Diabetic Retinopathy Study

FCR – Flexor Carpi Radialis

FI – Frailty Index

FNIRS – Functional Near-Infrared Spectroscopy

GS – Grip Strength

GV – Gait Velocity

HL – Hearing Loss

HRG – Hearing Handicap Inventory for the Elderly

HRQoL – Health-Related Quality of Life

HT – Hearing Threshold

IADL – Instrumental Activities of Daily Living

IBM – International Business Machines Corporation

ICF – International Classification of Functioning, Disability and Health

LNS – Letter-Number Sequencing

LSA – Life-Space Assessment

LSEQ – Listening Self-Efficacy Questionnaire

LSI – Life space index

MAD – Median Absolute Mediation

MAT – Mental Alternation Test

MMSE – Mini–Mental State Examination

MoCA – Montreal Cognitive Assessment

NSHA – Nova Scotia Health Authority

OA – Older Adults

oVEMP – Ocular Vestibular Evoked Myogenic Potential

PASE – Physical Activity Scale for the Elderly

PNS – Peripheral Nervous System

PTA – Pure-Tone Audiometry

RDD – Random Digit Dialing

SCD – Subjective Cognitive Decline

SCM – Sternocleidomastoid

SEM – Structural Equation Modeling

SLS – Single Leg Standing

SPPB – Short Physical Performance Battery

SPSS – Statistical Package for the Social Sciences

ST – Single Task

TA – Tibialis Anterior

TB – Triceps Brachii

TT – Triple-task

TUG – Timed Up and Go Test

VA – Visual Acuity

VEMP – Vestibular Evoked Myogenic Potentials

VL – Vastus Lateralis

VR – Virtual Reality

WAIS – Wechsler Adult Intelligence Scale

WHO – World Health Organization

YA – Younger Adults

Glossary

Biological Aging – Multisystem decline in physiologic reserve and function that accumulates over time[1]

Chronological Age – “A single time point away from the date of birth”[2]

Enteroception – “The reception of sensory stimuli from hollow internal organs.” [3]

Explanatory Variable – A variable representing a construct to be included in regression analysis, also sometimes referred to as covariate or independent variable.

Exteroception – “Sensitivity to stimuli originating outside of the body.” [4]

Frailty – “A clinically recognizable state of increased vulnerability, resulting from aging-associated decline in reserve and function across multiple physiologic systems such that the ability to cope with everyday or acute stressors is compromised.” [5]

Functional Mobility – “The manner in which people are able to move around in the environment in order to participate in the activities of daily living and, move from place to place. Movements include standing, bending, walking and climbing.”[6]

Healthy Aging – “The process of developing and maintaining the functional ability that enables wellbeing in older age.” [7]

Hearing Loss – “A person who is not able to hear as well as someone with normal hearing – hearing thresholds of 20 dB or better in both ears.” [8]

Life-Space Mobility – “Participants’ mobility within their home and community” [9]

Mobility – “The ability or tendency to move from one position to another” [10]

Proprioception – “The ability to sense stimuli arising within the body regarding position, motion, and equilibrium.”[11]

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CHAPTER 1 – INTRODUCTION

1.1 Introduction

Functional mobility limitations are prevalent among older adults, affecting nearly 30% of adults age 65 and older [12]. Difficulty in functional mobility, "the ability or tendency to move from one position to another" [10], often results in negative consequences for overall health[12]. For instance, individuals with mobility limitations often show increased risk of falls and fall-related injuries[13], more frequent localized pain[14], low social engagement[15], increased risk of developing depressive symptoms[16], lower Health-Related Quality of Life (HRQoL)[17], reduced preventive services compliance and increased healthcare utilization and expenditures[12].

The distribution of world's elderly population, aged 65 and older, is expected to increase dramatically, growing from 524 million in 2010 to nearly 1.5 billion in 2050 [18]. Based on Statistics Canada data, 12.6% of the total Canadians were within age of 65 and older in 2000[19], while this number increased to 18% in 2020 [19]. Accordingly, similar to global situations, the number of Canadians over the age of 65 will grow from 6 million in 2014 to over 9.5 million in 2030 [20]. Considering this accelerated growth in the aging population[18], a higher proportion of older adults with mobility limitations is expected, with associated increases in the demand on health and social services. Therefore, evidence about the factors that contribute to mobility limitations is needed to inform strategies to protect or restore the mobility of older adults and to reduce the associated burden on the health care system.

Functional Mobility is influenced by numerous physiological, personal, and environmental factors that are interrelated [21–23]. Demographic characteristics (e.g., age, sex), cognition, mental health status, diseases, and the surrounding physical and social environment are some of the factors that are associated with one's ability to be mobile [21–23]. Sensory systems influence mobility, providing reliable inputs such as visual, vestibular, proprioception information, needed for maintaining equilibrium in both standing and walking [21]. Therefore, knowledge of the impact of sensory impairments on mobility can be beneficial in protecting and restoring one's mobility.

Recent studies provide evidence about the contribution of hearing loss to balance and mobility problems. Hearing loss is one of the most prevalent health conditions in older adults [24]; the prevalence increases with age, increasing from 1.7% in children to 7% in adults between 15 to 65 years and to almost one in three in adults over 65 years old [18,25]. It often coexists with numerous health conditions, such as stroke, cancer, visual impairment, cognitive impairment, psychosocial health, diabetes, arthritis, cardiovascular risk factors and mobility issues [26]. Although, recent evidence suggests the potential role of hearing as a contributing factor to mobility, several limitations are evident across the studies. There are inconsistencies in evaluation methodologies and measures that limit the ability to examine the relationship between hearing and mobility in consideration of relevant factors, such as visual acuity. Thus, further research is needed to address the gaps and to better understand the relationship between hearing and mobility.

The Canadian Longitudinal Study on Aging (CLSA) is a 20-year longitudinal cohort study designed to help enhance longevity and quality of life of Canadians through understanding the processes involved in aging [27]. The CLSA provides an opportunity to examine the relationship between hearing and mobility in a large of group of participants using: Timed Up and Go (TUG) test, a reliable and valid tool which provides a continuous level of measurement for the evaluation of Functional Mobility [28], and Hearing Threshold measured through Pure-Tone Audiometry (PTA), the gold standard for hearing loss detection [29]. In addition, the CLSA contains a comprehensive set of other personal and environmental factors that permit more careful exploration of the relationship between hearing and mobility in consideration of the complex physiological, personal, and environmental factors that are known to influence mobility and/or hearing.

1.2 Purpose of the Study

The primary purpose of this exploratory study was to examine the relationship between Hearing Threshold and Functional Mobility, among older Canadians, using the data contained within the CLSA Comprehensive baseline assessment dataset. The secondary purpose was to examine further the relationship between Functional Mobility and Hearing Threshold in consideration of other designated factors (i.e., Visual Acuity Executive Function, Life-Space Mobility, and Frailty).

1.3 Specific Objectives

To address the primary and secondary research questions, the specific objectives of this study were:

1. To use descriptive statistics to identify the Hearing Threshold and Functional Mobility status of the cohort using the measures of Hearing Threshold and Functional Mobility included in the CLSA baseline dataset.
2. To test the strength and the form of the association between Hearing Threshold, measured by PTA, and Functional Mobility, measured by TUG test, when accounting for Age and Sex.

3. To examine the strength and the form of the bivariate relationships between Functional Mobility, Hearing Threshold and physiological and personal factors that could influence the relationship between Hearing Threshold and Functional Mobility (i.e., Age, Sex, Visual Acuity, Executive Function, Gait Velocity, Balance, Upper and Lower Extremity Strength, Life-Space Mobility, and Frailty) as an initial step toward the multivariate analysis.
4. To explore the multivariate relationships between Functional Mobility, Hearing Threshold, and the related factors (i.e., Visual Acuity, Executive Function, Life-Space Mobility, and Frailty), when adjusting for Age and Sex.

1.4 Hypotheses

1. Hearing Threshold is associated with Functional Mobility. Specifically, when Age and Sex are held constant, as Hearing Threshold increases, Functional Mobility decreases (Alternative Hypothesis, Objective 2).
2. a) <u>Functional Mobility</u> is associated with a number of designated explanatory variables. Specifically, as Functional Mobility decreases, Visual Acuity, Executive Function, Upper Extremity Strength, Lower Extremity Strength, Balance Function, Gait Velocity, and Life-Space Mobility decrease, whereas Frailty level increases. (Alternative Hypothesis).

   b) <u>Hearing Threshold</u> is associated with Visual Acuity, Executive Function, Upper and Lower Extremity Strength, Balance, Gait Velocity, Life-Space Mobility, and Frailty. Specifically, as Hearing Threshold increases, Visual Acuity, Executive Function, Upper Extremity Strength, Lower Extremity Strength, Balance Function, Gait Velocity, and Life-Space Mobility decrease, whereas Frailty level increases. (Alternative Hypothesis).

3. A significant portion of Functional Mobility variation is explained by Hearing Threshold, Visual Acuity, Executive Function, Life-Space Mobility, and Frailty. In other words, when controlling for Age and Sex, Hearing Threshold, Visual Acuity, Executive Function, Life-Space Mobility, and Frailty, each make a systematic contribution to Functional Mobility (Alternative Hypothesis, Objective 4).

CHAPTER 2 – REVIEW OF THE RELATED LITERATURE

2.1 Aging

Healthy aging, “the process of developing and maintaining the functional ability that enables wellbeing in older age” [7], is influenced by a variety of domains, collectively known as determinants of health. It can be promoted through managing health conditions, and it is, however, threatened by factors such as diseases, injuries, non-healthy behaviours (e.g., physical inactivity, smoking), health disparities, and barriers to accessing health care[30,31]. The physiological impact of these threats contribute to multisystem decline in physiologic reserve and function that accumulates over time [1], also known as biological aging which is distinct from chronological age. The World Health Organization (WHO) strategies to achieve healthy aging are grounded on the need to ameliorate biological and physiological losses, by addressing modifiable factors such as lifestyle, dietary habits, mental and environmental factors.

The WHO model of the International Classification of Functioning, Disability and Health (ICF) is a conceptual framework used across different sectors for describing functioning and disability [32]. Based on the ICF, an individual’s functioning occurs on a continuum, related to five domains: 1) Body Functions and Body Structures; 2) Activities; 3) Participation 4) Environmental Factors; and 5) Personal Factors. As illustrated in Figure 2.1, factors that influence healthy aging are classified within the five domains. For example, factors within the Body Function and Structures domain, such as hearing, visual, vestibular, and somatosensory impairments, muscle strength (Lower and Upper Extremity Strength) as well as mental and cognitive problems influence and are influenced by factors within the Activity domain (e.g., mobility, balance, gait, difficulty performing Activities of Daily Living (ADL)). By design, the WHO ICF model provides a robust framework to examine multifactorial relationships that contribute to healthy aging, including relationships among hearing and functional mobility of older adults.

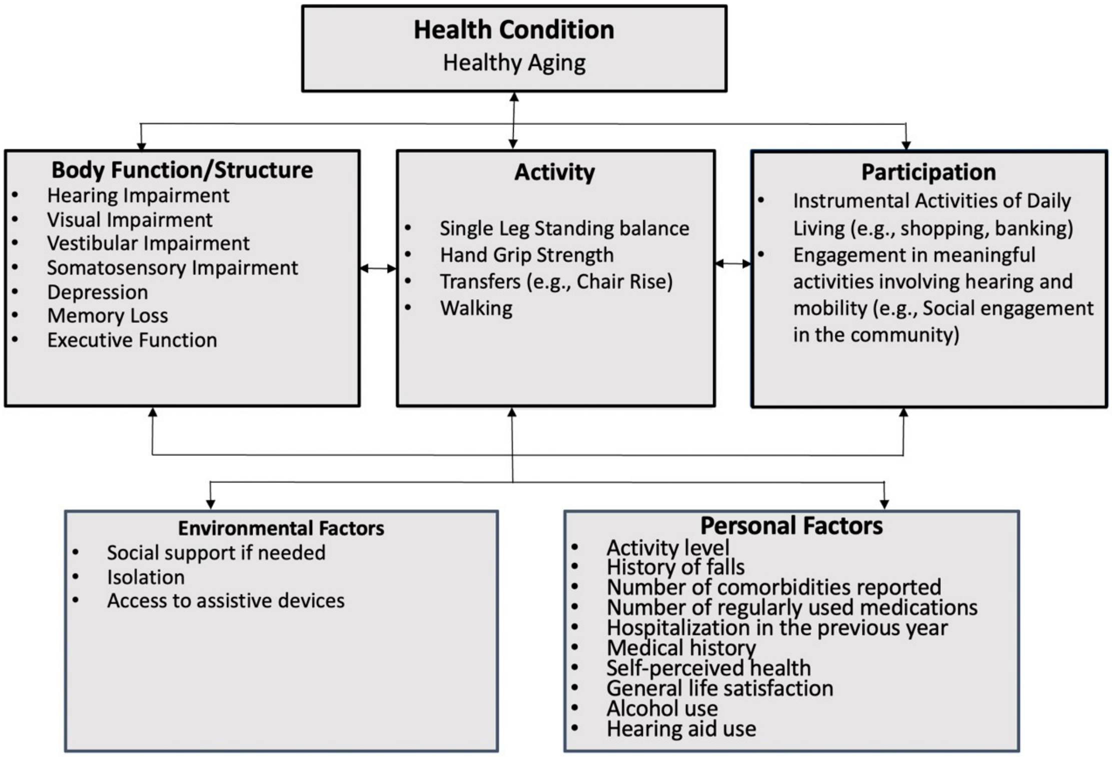

Figure 2.1: The WHO ICF framework for Health Aging, illustrating relationships among domains that capture Personal and Environmental Contextual factors, and domains that capture function in terms of physiological system (Body Structure and Function, basic skills (Activity), and meaningful roles (Participation). See text for details.

The prevalence of multimorbidity, “the presence of multiple diseases or conditions” [33], is projected to rise with chronological age[34], leading to a wide set of adverse outcomes in diagnosis, treatment and managing health conditions. The expected increase in the number of older people as well as the issues associated with multimorbidity development at older ages significantly increase the potential impacts of aging on older adults’ health and quality of life, as well as their demand for social and health services. Mobility limitations and hearing impairments are common health conditions in older adults, each affecting nearly 30% of the population aged 65 and older [12]. Both of these conditions often co-occur as multimorbidity [26,35]. Given the prevalence, and the physiological issues related to multimorbidity development, it is important to examine mobility limitations and the hearing loss to inform strategies to address this form of multi-morbidity and support healthy aging.

2.2 Mobility

2.2.1 The Contribution of Physiological Systems to Movement

Functional mobility is a complex construct, influenced by various interrelated factors [22]. Sociodemographic (e.g. age, sex), lifestyle (e.g. physical activity), diseases (e.g. foot and joint problems, metabolic syndrome), physiological factors (e.g. decreased muscle strength and bone mass) and frailty are some of the factors influencing mobility [22,36]. It requires the coordination of different physiological systems in the body including the nervous, musculoskeletal, sensory, cardiovascular and respiratory systems [37,38].

Circulatory and Respiratory Systems

The muscles and other physiological systems that control functional mobility, require adequate amount of oxygen and nutrients. Together, the cardiovascular and respiratory systems provide a constant supply of oxygen (O_2) and nutrition to skeletal muscles and remove carbon dioxide (CO_2) from them[39,40]. Deoxygenated blood is returned to the lungs, where the red blood cells exchange CO_2 for O_2 molecules and then, oxygenated blood travels along the pulmonary veins to the heart and from the heart to skeletal muscles[39,40].

Nervous System

The nervous system, as the control center for body movements, consists of the Central Nervous System (CNS) and the Peripheral Nervous System (PNS)[40,41]. The CNS includes brain and spinal cord[40], whereas the PNS contains cranial and spinal nerves, which are further subdivided into sensory (afferent) and motor (efferent) divisions[41,42].

Sensory System

The sensory part of the PNS, provides visual, auditory, vestibular, and somatosensory information (e.g., exteroception, proprioception and enteroception) about body position and motion. These sensory inputs are transmitted from the PNS to the CNS through ascending pathways (the afferent pathway) involving three sets of neurons: 1) First-order neurons are the primary sensory neurons that carry the input from the sensory receptors to the spinal cord, 2) Second-order neurons reside in the spinal cord or lower regions of the brain (e.g., medulla oblongata) and carry the input to the thalamus, and 3) Third-order neurons reside in the thalamus and carry the inputs from the thalamus to the appropriate sensory area of the cerebral cortex [41,43]. Thus, processing the sensory inputs, also known as sensory integration, happens within both the brain and the spinal cord[41], to help control posture, balance and mobility.

The sensory inputs to specific areas of the brain are used to activate different components of the musculoskeletal system through the efferent pathways, also known as descending pathways, to recruit skeletal muscles that stabilize posture, and generate movements for balance and mobility. These pathways involve upper and lower motor neurons which take the information from the CNS to the skeletal muscles[41]. The upper motor neurons begin in the cerebral cortex and connect to the lower motor neurons, via the interneurons, in the anterior horn of the spinal cord[41]. The lower motor neurons begin in the spinal cord and synapse on the muscle fibers forming neuromuscular junction[41,44]. Somatic motor neurons, a type of lower motor neurons, innervate skeletal muscles which are responsible for both voluntary and involuntary (e.g., reflexes) movements[44]. For the voluntary movements, the motor commands travel from the primary motor cortex to the brainstem, cross over to the opposite side of the spinal cord (decussation) for the purpose of contralateral control and exit through the ventral root of the spinal cord[41].

Reflexes, "an involuntary and nearly instantaneous movement in response to a stimulus"[45], involve a different pathway from receptors to the effector. In a reflex, sensory inputs travel along the afferent pathway to the integration center located in the brain or the spinal cord[41]. Reflexes can be classified as monosynaptic and polysynaptic reflexes depending on the number of synapses and the neurons involved [46]. A monosynaptic reflex (e.g., patellar tendon reflex, also known as stretch reflex) is a simple reflex involving one synapse between a sensory neuron and a motor neuron[46]. While in a polysynaptic reflex (e.g., withdrawal reflex), the reflex involves more than one synapse and one or more interneurons[46].

Musculoskeletal System

One of the main body systems involved in movements is the musculoskeletal system which consists of bones, cartilage, skeletal muscles, joints, and connective tissues (e.g., Tendons, ligaments) and is controlled by the nervous system[40]. As the motor commands, the action potentials, exit the ventral root of the spinal cord, they travel along the efferent axons, activating the neuromuscular junction through releasing a neurotransmitter (e.g., acetylcholine) [40,41]. This activation (depolarization of the muscle cell membrane) leads to excitation-contraction coupling which releases calcium (Ca^{2+}) from the sarcoplasmic reticulum into the cytosol of the muscle cell which leads to the movement of actin and contraction of the muscle cell [40,41].

Skeletal Muscle Function for Balance and Mobility

Three types of muscles (skeletal, cardiac, and smooth) [41], contribute to different muscle functions. Respiration, blood circulation, digestion, temperature regulation, mobility, stability, and postural control are some of the main functions of the muscles. Producing movements, maintaining posture and stability are the primary functions of the skeletal muscles [47]. Skeletal muscle ability to generate movement is influenced by muscular strength, power, endurance, and coordination. For instance, lower levels of muscle strength, “the ability to generate maximal muscle force” [48], and muscle power ,“the product of the force and speed at which movement occurs” [48], are associated with poorer functional ability in activities of daily living [49–52]. Muscle endurance, which is “the ability of a muscle to maintain its function throughout time and multiple contractions” [53], and muscle coordination, as “the distribution of muscle force (or torque) among the muscles to involved in a given motor task” [54], are necessary in stabilizing the body and to maintain equilibrium while we are moving.

Decline in skeletal muscle function is often observed as chronological age increases. Changes in muscle mass, hormones, and the level of physical activity are some of the factors influencing the decline[55–60]. However, as summarized in a robust systematic review, appropriate levels of physical activity and properly prescribed exercise protect or restore muscle function, reduce rate of falls, and improve gait ability, balance, and strength performance in older adults [61].

2.2.2 Maintaining Balance and Equilibrium

Vestibular system

The vestibule (utricle and saccule) and the three semi-circular canals of the inner ear contain specialized sensory receptors that provide important information for balance and mobility [41,62]. The semi-circular canals are filled with endolymph (Scarpa's fluid)[41]. Endolymph motion causes the movement of stereocilia (fibers connected to hair cells) which results in sending the information related to angular motion of head to the brain[41,63]. The vestibule (utricle and saccule), referred to as otolith organs, detects linear acceleration and gravitational forces [41,63]. Otoliths, “small calcium carbonate crystals” [63] embedded within the membrane, move in response to head movements, which in turn moves Endolymph and the hair cells[41,63]. Movement of the hair cells send the related information to the brain[41,63]. The utricle provides information related to movement in the horizontal plane, while the saccule provides information related to movement in vertical plane [63]. The signals from the vestibular system are sent to the brain by the vestibular part of the vestibulocochlear nerve (CN VIII) [41,63].

Vestibular-Dependent Reflexes (VEMPs)

Vestibular Evoked Myogenic Potentials (VEMP) reflexes mediated by the vestibular system in response to acoustic stimuli [64,65]. VEMPs can be recorded from upper and lower limb muscles including deltoid, biceps brachii (BB), triceps brachii (TB), flexor carpi radialis (FCR), extensor digitorum communis (EDC), abductor digiti minimi (ADM), vastus lateralis (VL), tibialis anterior (TA), gastrocnemius and abductor hallucis (AH) muscles [64]. The cervical Vestibular Evoked Myogenic Potential (cVEMP) is recorded from the sternocleidomastoid (SCM) muscles in the neck, while the ocular

Vestibular Evoked Myogenic Potential (oVEMP) is recorded from the inferior oblique muscle [64,65].

The cVEMP pathway starts from acoustic stimuli activating otolith organs (mainly the sacculus for SCM muscle and the utricle for the inferior oblique muscle), responsible for perception of linear acceleration, ultimately sending signals down the inferior vestibular nerve, to the vestibular nucleus and then to the descending vestibular spinal pathway, producing an inhibitory change in the SCM muscle tone [66]. The VEMPs are measured with electromyography (EMG), providing a measure of the function of otolith organs and vestibular nerve [66]. Furthermore, the VEMPs evoked by the acoustic stimuli demonstrate the connection between the auditory system and the postural reflexes controlling head and body orientation.

Visual and Somatosensory Systems

In maintaining balance and equilibrium, in addition to the vestibular system, visual and somatosensory systems provide sensory feedbacks to the nervous system in regards with the orientation of the body and the surrounding environment [67]. Visual signals are sent via the optic nerve from the retina to the primary visual cortex located in the back of the brain[41]. While, proprioceptive and exteroceptive receptors (e.g., muscle spindles, Golgi tendon organs, joint receptors and cutaneous receptors) transmit information through the ascending pathways (e.g., dorsal column medial lemniscal, anterior and posterior spinocerebellar tract and spinoreticular tract) to the cerebral cortex [67].

2.3 Hearing

2.3.1 Anatomy

For the sense of hearing, the human ear detects and converts sound waves produced in the external environment to neural impulses for further integration within the brain. The human ear is divided into three parts: the outer, middle, and inner ear[41]. The outer ear consists of the auricle (pinna) and the ear canal which directs the sound waves to tympanic membrane, causing it to vibrate[41]. The vibration of the tympanic membrane transfers the sound waves to the middle ear, which is made up of three bones: the malleus (hammer), the incus (anvil), and the stapes (stirrup) [41]. The vibration of the tympanic membrane results in movement of these three bones, which pushes the oval window in the inner ear [41]. This action transforms the mechanical vibrations in the air to vibrations in the cochlear fluids. The movement of the oval window passes the vibration onto the cochlea, a fluid-containing membrane bounded space in the petrous part of the temporal bone [41,68]. The cochlea contains three chambers: the Scala vestibuli, the Scala media (also known as cochlear duct) and the Scala tympani [40,41]. The vibrations in the cochlear fluid, generated by the movement of the oval window, lead to the vibration of the Basilar membrane and consequently the organ of Corti[40,41].

The organ of Corti contains the sensory receptors, also known as hair cells, responsible for the process of hearing [40,41]. Each hair cell contains a bundle of smaller hair cells (stereocilia) [41]. The vibration of the Basilar membrane and the organ of Corti results in the movement of Tectorial membrane which bend the stereocilia [40,41]. When the stereocilia bend, this action opens the cation channels (K+), which depolarizes the hair cell causing it to release neurotransmitter to afferent neurons[40]. These afferent neurons transmit neural impulses to the brain by the vestibulocochlear nerve (CN VIII), which consists of two parts: the cochlear nerve and the vestibular nerve[40,41]. The cochlear nerve carries the auditory information encoded in the form of neural impulses, also known as action potentials, while the vestibular nerve carries the information coming from the vestibular system[41].

Auditory Pathways

The neural impulses carried to the primary auditory cortex and from the auditory cortex to other locations involve two auditory pathways: the ascending auditory pathway and the descending auditory pathway. Along the ascending pathway, the neural impulses, providing the auditory information travel along the cochlear nerve to the medullary olives, inferior colliculus, thalamus, and finally to the auditory cortex located on each side of the brain[40,41]. The descending auditory pathway can be considered as being reciprocal to the ascending pathway, travelling from the auditory cortex back to the inferior colliculus, superior olivary complex, cochlear nucleus, and finally to the cochlear hair cells [69,70].

2.3.2 Sound Characteristics

As a sound wave travels through the air, it creates areas of higher or lower pressures. These changes in pressure make the eardrum vibrate [40,41]. Thus, during the process of hearing, physical characteristics of a sound wave such as intensity (amplitude) and pitch (frequency) are detected. The perception of the sound loudness represents the amplitude of a sound wave, which is measured in decibels (dB) [40,41,71]. Sound waves with larger amplitude, high pressure areas, are perceived as louder (higher decibel level)[41]. The normal human ear can detect sound waves ranging from 0 to 130 dB[71], while the sound levels of a normal conversation is about 60 dB [72]. The perception of the sound frequency, which is detected in cochlea, represents the pitch of a sound, measured in cycles per second, or hertz (Hz) [71]. Though the sound frequency normally ranges from 20 to 20,000 hertz for human hearing[71], the speech frequency of an adult ranges from 500 to 4000 Hz[73].

2.3.3 Hearing Loss

One of the most prevalent health conditions in the elderly population is hearing loss, which is defined as partial or total inability to hear certain frequencies [24,74]. Depending on the location of the damage to the auditory system, hearing loss can be conductive, sensorineural or mixed hearing loss [74]. Mechanical disruption of the external and middle ear, which reduces the ability to transfer sound vibrations, leads to conductive hearing loss[75]. Whereas, damage to the hair cells, the auditory nerve or the auditory centres along the auditory pathway, results in failure to transmit neural impulses resulting in sensorineural hearing loss[74]. A combination of conductive and sensorineural hearing loss would result in a mixed hearing loss [74].

Common Causes of Hearing Loss

Hearing loss can be developed at any age, and caused by various physiological and environmental factors. Depending on the presence of hearing loss at the birth (congenital) or after the birth (acquired)[74], it may be caused by factors including aging (presbycusis), structural abnormalities, genetic conditions, infection/ inflammation, toxicity, neoplasm, trauma and loud sound exposure [74,76]. Conductive hearing loss most commonly occurs as a long term consequence of otitis media. Structural abnormalities are rare congenital causes of conductive hearing loss[74]. Some of congenital causes of sensorineural hearing loss can be genetic conditions (about 50% of cases), infections (cytomegalovirus, rubella, mumps and etc.), extracorporeal membrane oxygenation (hyperbilirubinemia, kernicterus), while the acquired causes can be trauma, high intensity noises, ototoxic medications and meningitis [74].

Aging is one of the most common causes of hearing loss in adults. Age-related hearing loss (presbycusis) which often results in difficulties hearing high-frequency sound waves (i.e., 3000, 4000, 6000, and 8000 Hz)[73,76], is caused by damage to hair cells, and other cells in the inner ear (e.g. nerve cells, stria vascularis) [76]. Individuals with age-related hearing loss have normal perception of low-frequency sounds and only difficulty in distingushing high-frquency sounds [76]. However, as their condition progresses, their perception of middle and low-frequency sounds can also be affected [76].

Evaluation and Classification

In general, hearing loss can be evaluated through different kinds of assessments. The most common ones are self-rated questionaries as well as behavioural measurements (i.e., Pure-Tone Audiometry)[77,78]. As illustrated in Table 2.1, the degree of hearing loss measured through PTA can be categorized into six categories based on the average of hearing threshold at each level[79].

Table 2.1. Classification of hearing loss according to Stevens et al. (2013)[79].

Degree of hearing loss	Range (dB)
Normal	Less than 20
Mild	20 to 34
Moderate	35 to 49
Moderately Severe	50 to 64
Severe	65 to 79
Profound	80 to 94

Hearing Loss Consequences

As summarized in a systematic review published in 2018, hearing loss is associated with health conditions including but not limited to psychological health, cognitive impairment, frailty, physical activity and mobility limitations [26].

Psychosocial Health

Hearing loss is associated with increased risk of psychological problems. Individuals with hearing loss compared with the general population are less likely to engage in social interactions [81]; this is mostly due to the influence of hearing on the ability to communicate with other people effectively [26]. These individuals show increased social isolation, lower level of mood and social engagement, and more emotional loneliness [26,81–83]. In addition, they tend to have greater risk of anxiety, greater risk of depression, more frequent depressive episodes and more depressive symptoms compared with the individuals who have normal hearing [26,84,85].

Cognitive Impairment

Recent evidence demonstrates that the prevalence and incidence of cognitive impairment in individuals with hearing loss is higher compared to individuals with intact hearing [26]. For example, the rate of cognitive decline and/or dementia as well as the prevalence and the incidence of dementia are reported to be higher in hearing impaired individuals [26,86,87]. Moreover, a higher degree of hearing loss was related to greater risks for the incidence of dementia [26,88].

Frailty

A recent longitudinal study suggested that frailty is associated with hearing impairment[26,89]. In this study, the participants were grouped into not frail, pre-frail and frail categories based on five frailty phenotype components: slow walking, weak grip, self-reported exhaustion, weight loss and low physical activity. After a four-year follow-up, the results revealed that prefrail individuals with hearing loss had greater risk of becoming frail within four years. Therefore, frailty, as one of the challenges associated with aging, may coexist with hearing loss in older adults [26].

Physical Activity

Previous studies support the association between hearing and levels of physical activity in individuals with hearing loss compared to those with normal hearing. Physical activity was measured in a variety of ways across these papers. Wells and colleagues [90] explored the associations between self-reported hearing loss (aided/unaided) and self-reported physical activity as measured the frequency of physical exercise and the need to stay at home. They found that in older adults, unaided severe hearing loss was associated with lower probability of exercise more than four days per week, as well as lower probability of leaving the home. Gispen and colleagues [91] looked at the associations between moderate and greater hearing loss and physical activity measured by accelerometer in adults aged 70 and older. The results revealed an association between hearing loss and lower levels of physical activity, meaning that those with moderate or severe hearing loss had 70% greater odds of having less physical activity. Therefore, evidence supports the association between hearing loss and the level of physical activity in older adults.

Mobility Limitations

As previously described, reliable inputs from the sensory systems are used to maintain balance in both standing and walking [21]. Early studies support the theory that hearing loss may also associate with poorer mobility. There are theories explaining the potential mechanisms that are in play for the association between hearing loss and mobility limitations. The specific detail of each is discussed below[92–96].

The Proposed Mechanisms Linking Hearing Loss with Mobility Limitations

Self-motion perception, as the name implies, is an individuals' perception of his/her own movement through space [93]. Estimation of one's motion relative to objects within a complex environment requires the neural combination of auditory cues and other sensory inputs from visual, vestibular, tactile, and proprioceptive systems [93]. For example, orientation of one's body position in space can be informed by monaural and binaural auditory cues derived from a sound source in a room[93]. Additionally, one's footstep sounds may provide temporal cues that provide feedback to help control balance during walking[97]. Hearing impaired individuals may have impaired self-motion perception due to the difficulty using the auditory cues for sound localization, and detection of dynamic changes in their own motion as well as the surrounding environment [93]. Self-motion perception is also influenced by use of hearing aids, but more research is needed to understand the specific impact of using these types of devices [93]. Overall, the evidence supports consideration of the theory that hearing loss may contribute to impaired self-motion perception and ultimately can have a disruptive impact on mobility and postural stability [93].

Efficient allocation of attentional resources is required for safe mobility in older adults. In general, attentional resources are devoted efficiently between tasks in accordance with priority and importance. Failure in efficient allocation of attentional resources may lead to balance and mobility deficits, especially in multitask conditions[94,95]. For instance, Rosso and colleagues [94] investigated the changes in brain activations when participants (both younger and older adults) simultaneously performed an auditory Choice Reaction Task (CRT) and a mobility task (standing on a dynamic posturography platform). According to the results, during dual-tasks which require attention, the neural resources needed for balance control are reduced. These results are consistent with other studies demonstrating deficits in postural control when older adults engage in more than one task that require attentional resources [92,95]. In hearing impaired individuals, sound processing requires more cognitive demands due to their increased listening effort[98,99]. This ultimately may challenge the available attentional resources, leading to balance and mobility deficits in multitask conditions. Given the information provided, it is expected that the combination of cognitive impairment and hearing loss in an individual increases the associated challenges to mobility even further. Therefore, it is helpful to examine hearing and mobility in consideration of cognition.

Decreased social interactions observed in hearing impaired individuals[26,81] may also link hearing loss with mobility limitations. It is expected that the increased social isolation decreases the level of physical activity, as well as cognitive stimulations in hearing impaired individuals. Given the importance of physical activity in functional mobility, the decreased level of physical activity may lead to balance and mobility challenges. Furthermore, the decreased cognitive stimulations increase the rate of cognitive decline over time[100–102], which ultimately may lead to balance and mobility deficits through the mechanism discussed before. Therefore, social isolation is another important factor that should be considered in studying the relationship between hearing and mobility.

The decline in auditory and vestibular systems, responsible for the process of hearing and maintaining equilibrium, may occur concurrently. According to Zuniga and colleagues [96], concurrent declines in both the cochlea, as the main organ involved in the process of hearing, and the saccule, responsible for the detection of vertical linear movements, occur, possibly due to their common embryologic origin[96]. Moreover, the decline in both organs is associated with aging as well as noise exposure [96]. Thus, hearing impaired individuals, especially those with age-related hearing loss as well as significant noise exposure history, are more likely to develop saccular dysfunction, and ultimately more balance deficits.

2.4 Experimental Evidence on the Relationship between Hearing and Mobility

The available evidence on the association between hearing loss and mobility limitations mostly comes from performance-based studies involving single- and/or dual-task paradigms. A previous study by Koh and colleagues [103] was done to examine the relationship between hearing measured by PTA and dynamic balance ability, measured by TUG test, in 46 Korean individuals aged 65 and older. According to the results of the correlation analysis, systematic association between the TUG score and the better ear hearing level threshold was not found[103]. However, the authors found no significant difference in TUG scores between normal hearing group and hearing loss group[103].

Other studies often aim to examine this relationship, with the use of a variety of methodologies and outcome measures as well as lack of consideration of many physiological, personal, and environmental factors limit our understanding of the potential interaction between hearing and mobility. For the aim of exploring the evidence on the influence of hearing loss on mobility, ten related studies were summarized (Appendix A), and appraised.

2.4.1 Sample Characteristics

The population sampled varied across the studies as summarized in Appendix A. All studies included males and females. Participants' ages ranged from 18 to 90; some of the studies focused on the performance of older adults [104–107], while others allowed comparisons of the older adults to younger adults [94,108–111].

As illustrated in Appendix A, there are notable inconsistencies as well as gaps across the reviewed studies regarding to the assessment of participants characteristics. Participants' mobility/ balance was assessed in six studies as inclusion/ exclusion criteria or part of the pre-screening process. As shown in Appendix A, some of the inclusion/ exclusion criteria related to mobility include the self-reported difficulty in mobility/balance abilities; self-reported medical conditions affecting mobility/balance; scores ≤ 19 for Dynamic Gait Index (DGI). All studies included participants with no cognitive impairment, except Bang and colleagues[112] that did not screen for cognition. No studies explored the level of physical activity in participants.

Hearing status was also assessed using a variety of methods, including: self-reported hearing loss (e.g., single question), air conduction pure-tone audiometry; Listening Self-Efficacy Questionnaire (LSEQ). As illustrated in Appendix A, hearing status was measured in eight studies, seven studies used air-conduction pure-tone audiometry at varied frequencies [104,105,107–110,112]; one study used self-reported questionnaire[106], while Bruce and colleagues [108] used both pure-tone audiometry and LSEQ. Self-reported hearing questionnaire, based on subjective self-assessment of individuals, often leads to over- or underestimation of the prevalence of hearing loss in older adults[113]. Whereas pure-tone audiometry as the gold standard for hearing loss detection has high test-retest reliability [29]. In summary, there are inconsistencies in methods used to measure hearing, which constrain the quality of evidence available to examine relationships among hearing, balance, and mobility.

2.4.2 Task Paradigms

The contribution of hearing to mobility has been investigated with the use of single- and dual-task paradigms, providing insight into the association between hearing and mobility as well as the potential mechanisms underlying this possible interaction. From the reviewed studies, two studies [106,112], involved single-task performance tests to examine the impact of hearing loss on balance and mobility. Mikkola and colleagues [106] examined the association between hearing loss and physical performance, as well as self-reported difficulties in mobility in older adults aged 75 to 90. For this purpose, they used the Short Physical Performance Battery (SPPB) test to assess lower limb physical performance and a self-reported questionnaire for the evaluation of the participants' difficulties in mobility. The results revealed an association between major hearing loss and lower SPPB scores which is an indicator of poor balance. Bang and colleagues[112] examined the association between hearing loss and postural instability with the use of static posturography. Accordingly, the participants were asked to stand on a foam surface with eyes closed or eyes open. The results revealed an association between moderate or worse hearing loss and postural instability in hearing impaired individuals.

The impact of performing motor-cognitive (auditory-related) dual- and triple-tasks has been investigated across studies with or without consideration of participants' hearing level. Rosso and colleagues [94] examined the influence of an auditory-related cognitive task on postural control by comparing the participants' brain activations during single- and dual-task conditions involving a postural control task (dynamic posturography) and an auditory CRT task. The results revealed that during a dual-task performance in older adults, neural resources dedicated to postural control are reduced to a greater extent than during the single-task conditions. Additionally, Plummer-D'Amato and colleagues[111] examined the effect of performing an auditory Stroop task on gait in both young and older adults. The results demonstrated significant dual-task interference during the Stroop task in older adults. Despite the lack of screening for hearing level, these papers provide some support for the negative impact of performing an auditory-related task and a motor task concurrently on balance and mobility.

Considering the importance of the auditory system in the performance of the auditory-related tasks (e.g., CRT, Stroop task), the studies screening the participants' hearing level are more informative [104,105,107–110]. Across these papers, as illustrated in

Appendix A, mobility as the main outcome of interest was assessed under a variety of conditions including sitting, standing, perturbed standing and walking. According to the results, the combination of the postural tasks (e.g., sitting, standing, perturbed standing or walking) with an auditory task resulted in poorer mobility/balance, demonstrating a multi-task interference [105,107]. Although, brain activations show the prioritization of postural task over the auditory task [105], with greater prioritization in older adults than younger adults [110], the reduction in neural resources dedicated to postural control as well as dual-task interference/costs cannot be ignored, especially in hearing impaired older adults. According to Bruce and colleagues [108], these individuals show greater dual-task interference/cost compared to age matched control group.

2.4.3 Key Contributions and Limitations in the Evidence

Considering the implications that mobility limitations, hearing loss and their common comorbidities have for older adults, understanding the potential interactions between hearing, mobility, and the set of designated factors is essential in informing management and protection strategies that improve mobility of older adults. The studies included in this review support the association between hearing and mobility. Moreover, these studies demonstrate the dual-task costs on the performance of both auditory-related task and mobility task, especially in older adults. However, there are several limitations across the studies. The populations sampled varied regarding geographic location (e.g., Canada, United States, Finland, Norway, Brazil, United Kingdom, Italy, Australia, and France), age (18 to 90 years old), sex and the number of participants. While these early studies support the theory that hearing loss may contribute to mobility limitations, little attention has been given to the confounding effects of the variables related to hearing and/or mobility (e.g., somatosensory function, vestibular function, vision, upper and lower extremity muscle strength, cognitive impairment, balance, physical activity, life-space mobility, and frailty). Additionally, across these papers, various evaluation methodologies were used to measure hearing (e.g., self-reported hearing and pure-tone audiometry) and mobility (e.g., sitting, standing, perturbed standing and walking), which limits our ability to compare between studies. Moreover, the use of self-report measures limits the discrimination of the hearing level compared to the more objective and responsive measures.

Though many studies support the association between hearing and functional mobility in older adults, there is controversy in the findings. Given the inconsistencies in evaluation methodologies, measures, and the findings, it is difficult to identify the potential interaction between hearing and mobility as we compare the studies. In addition, it is not clear if the observed relationship between hearing and mobility is confounded by other factors. The use of reliable and valid assessment tools for the evaluation of hearing and mobility as well as the inclusion of related factors will enable us to better understand the association between hearing and mobility as well as the impact of the factors on this association.

2.5 The Canadian Longitudinal Study on Aging (CLSA)

The Canadian Longitudinal Study on Aging (CLSA) has a sample consisting of 51,338 participants between the ages of 45 to 85 years old at the time of recruitment. It includes two separate complementary cohorts that are studied using different data collection methods: 1) Tracking cohort: 21,241 randomly selected participants from all 10 Canadian provinces, and data collection via a 60-min Computer-Assisted Telephone

Interview (CATI), ; and 2) Comprehensive cohort: data collected both by in-person home interviews (Computer-Assisted Personal Interview (CAPI)) and by in-depth physical information collected onsite at one of 11 Data Collection Sites (DCS) located in seven Canadian provinces (Saskatchewan, New Brunswick and Prince Edward Island were excluded) from 30,097 randomly selected participants that are within 25–50 km of one of the DCSs[114]. In both cohorts, the participants are followed-up for 20 years, with a 3-years interval, until 2033 or until death [114].

The CLSA provides an extensive set of variables that can be organized around seven general domains: 1) biology, 2) clinical, 3) health outcomes, 4) health services, 5) lifestyle, 6) psychology, and 7) social [27]. These variables allow us to examine the relationships between functional mobility, hearing, and other related factors. Specifically, the baseline dataset of the comprehensive cohort, contains variables that span the ICF domains, including objective measures of Functional Mobility (the Time Up and Go test), Hearing Threshold obtained via Pure-Tone Audiometry, Vision, Cognition, Upper and Lower Extremity Strength, Balance, Life-Space Mobility, and Frailty. Exploratory analyses are well suited to examine the relationships among hearing and mobility, in the context of relevant factors across the ICF domains, and gain information to address gaps in the literature and to inform strategies that promote healthy aging.

CHAPTER 3 – METHODOLOGY

3.1 Research Design

A secondary exploratory cross-sectional analysis of the CLSA Baseline Comprehensive Dataset was conducted.

3.2 Data Acquisition

Access to the CLSA baseline dataset was obtained according to the required procedures. To obtain the CLSA data, the research team applied for access according to the required procedures [115].

3.3 Study Sample

Participants aged 65 to 85 years, in the CLSA Baseline Comprehensive cohort were included in this study. For the CLSA data collection, a sample of 51,338 community-dwelling Canadian were randomly recruited from: 1) the participants in the Statistics Canada's Canadian Community Health Survey-Healthy Aging (CCHS-HA); 2) the registries of provincial health care systems; and 3) Random Digit Dialing (RDD) of landline telephones [114]. The participants were excluded from the baseline data collection if they were residents of the three territories, were full-time members of the Canadian Armed Forces, or if they lived on federal First Nations reserves; those who lived in other First Nations settlements in the provinces, or long-term institutions (institutions providing 24-hour nursing care), and those who were temporary visa holders or had transitional health coverage were also excluded [27]. Additionally, individuals who were unable to respond in English or French, as well as individuals with cognitive impairment were excluded [27].

3.4 Ethical Considerations

All the CLSA protocols were approved by 13 research ethics board across Canada [116]. Additionally, the approved users and institution agreed on the security measures implanted for the safe storage and transfer of the derived data according to the CLSA data access agreement.

As per Tri-council Policy Statement article 2.4, and confirmed by the Nova Scotia Health Authority (NSHA) research ethics board, ethics approval was not required for this secondary data analysis.

3.5 Variables

The variables for this study, classified using the ICF Domains, and paired with the corresponding data collection methodology, are summarized in Table 3.1. Details of the data collection methods and scoring procedures are provided below.

Table 3.1: Classification of the variables and the measurement tools based on ICF domains.

ICF Domains	Constructs	Variables	Units
Body Function and Structure	Hearing Threshold	Pure-tone audiometry Hearing Threshold	dB
	Hearing Status	Self-reported hearing Status	N/A
	Visual Acuity	Early Treatment Diabetic Retinopathy Study chart score	logMAR
	Executive Function	Mental Alternation Test score	N/A
	Upper Extremity Strength	Hand grip strength score	kg
Activity	Functional Mobility	Timed Up-and-Go Test scores	s
	Balance	Single Leg Standing Test Score	s
	Gait Velocity	Timed 4-Meter Walk Test Score	$m.s^{-1}$
	Lower Extremity Strength	Chair Rise Test Score	s
Participation	Life-Space Mobility	Life Space Index	N/A
Environmental Factors	Assistive Devices	Self-reported Assistive devices	N/A
Personal Factors	Frailty	Frailty index	N/A
	Fall History	Self-reported Fall history	N/A
	Hearing Aid Use	Self-reported Hearing aid use	N/A
	Age	Self-reported Age	years
	Sex	Self-reported Sex	N/A
	Sexual Orientation	Self-reported Sexual Orientation	N/A
	Standing Height	Height	cm
	Weight	Weight	kg
	Ethnicity	Self-reported Ethnicity	N/A
	Country of Birth	Self-reported Country of Birth	N/A
	Racial Background	Self-reported Racial background	N/A
	Education	Self-reported Education	N/A
	Marital/Partner Status	Self-reported Marital/partner status	N/A
	Income	Self-reported Income	N/A
	Employment Status	Self-reported Employment status	N/A

3.5.1 Body Function and Structure

Hearing

In the CLSA Comprehensive cohort, hearing was evaluated by both self-report and Pure-Tone Audiometry (PTA). While the self-report assessment of hearing was included as a measure of Hearing Status to help describe the characteristics of the sample, Pure-Tone Audiometry, the gold standard for hearing loss detection with high test-retest reliability[29], was used as the primary measure of hearing in this study.

Hearing Threshold (Independent Variable)

Unaided Hearing Threshold was measured using an automated digital screening audiometer at 0.5,1, 2, 3, 4, 6, 8 kHz test frequencies (recorded from 0 to 100 dB hearing level in 5 dB steps [117,118]) for both ears [117,119]; a constant value of 105 dB was used when participants had "no responses" to the test[117,120]. According to CLSA protocols, this audiometer, supplemented with audiocup headphones, can be administrated in a quiet room and a soundproof room is not required[121]. The details of the CLSA procedure for measuring hearing Threshold can be found in Hearing-Audiometer Data Collection Site (DCS) Protocol Version 3.0 document [119]. Based on the CLSA protocol, the participants were not allowed to use hearing aids, sound processors, cochlear implants, or any external processors. Therefore, the individuals with lyric or bone anchored hearing aid are not included in the dataset used for this study.

For each participant, the Hearing Threshold (HT) measured at each frequency for each ear was extracted from the CLSA dataset. The mean HT for each ear (i.e., HT_{Right}, HT_{Left}) was calculated as the average of the thresholds obtained from each measured frequency[108]. Four HT variables were calculated as the average of the right and left ears, to differentiate HT as a function of the test frequencies that were included in the calculation: 1) $HT_{AllFreq}$ (all measured frequencies: 0.5, 1, 2, 3, 4, 6 and 8 kHz), 2) $HT_{LowFreq}$ (low frequencies: 0.5, 1, and 2 kHz), 3) $HT_{SpeechFreq}$ (speech frequencies: 0.5, 1, 2, 3, and 4 kHz), and 4) $HT_{HighFreq}$ (high frequencies: 3, 4, 6, and 8 kHz)[73]. The HT values were used to classify hearing status in 6 categories: 1) <20 dB normal hearing, 2) 20-34 dB mild hearing loss, 3) 35-49 dB moderate hearing loss, 4) 50-64 dB moderately severe hearing loss, 5) 65-79 dB severe hearing loss, and 6) 80-94 dB profound hearing loss[80].

To identify the HT variable to be used in testing the research hypotheses, a correlation matrix was computed using the HT variables (i.e., $HT_{AllFreq}$, $HT_{LowFreq}$, $HT_{SpeechFreq}$, and $HT_{HighFreq}$) and TUG scores. Since the assumptions of correlation were met, a Pearson's Product-Moment Correlation Coefficient (r) (2-tailed) was used. Pearson's correlation coefficients as well as 95% CIs are presented in Appendix B. According to the results, all HT means were significantly related to TUG score. The HT that shared the highest correlation coefficient with the TUG scores, $HT_{AllFreq}$ (r=0.171, 95% CI [0.154, 0.189], p<0.001) was selected for subsequent analyses (Objectives 2-4).

Vision

Visual Acuity (VA) scores as a measure of vision were obtained from the baseline CLSA dataset. In the CLSA, Visual Acuity was measured in logMAR using an illuminated Early Treatment Diabetic Retinopathy Study (ETDRS) chart, a standard tool for the evaluation of visual acuity [122]. The details of the testing procedure can be found in the CLSA Vision – Visual Acuity Protocol Version 2.1 document [123]. Based on the protocol, the participants were allowed to wear their regular glasses or contact lenses; the chart was positioned 2 meters from the participant's eyes[123]. The measured Visual Acuity scores can be evaluated as: Normal (≤ 0.3 logMAR), Mild to Moderate ($0.3 <$ logMAR < 1.0), and Severe (logMAR ≥ 1.0) impairment[124].

Cognition

The Mental Alternation Test (MAT) was selected as a measure of Executive Function in this study[125]. The MAT which can be administrated within a short period of time[126,127], has been shown to have good sensitivity (91%) and specificity (100%) to cognitive impairment detected by the MMSE [126]. The details of the testing procedure can be found in the CLSA Cognition (COG) – In-home Visit document[128]. The MAT includes three tasks that each should be done within 30 seconds: Task 1, counting from 1 to 20; Task 2, verbally reciting the English alphabet; and, Task 3, alternating consecutive numbers and alphabetical letters[128]. The scores for the MAT, ranging from 0 to 51, represent the number of correct alternations done during the test between alternating consecutive numbers and alphabetical letters[128]. Scores 15 or below correspond to abnormal MMSE (MMSE score <24)[127]. Scores 15 and above indicate normal Executive Function[127].

Upper Extremity Strength

Hand grip strength (GS) was used as an indicator of the participants' upper extremity strength [129]. In the CLSA, hand grip strength was measured in kilograms (kg) using a hand grip dynamometer. Detailed description of the hand grip strength test and the exclusion criteria can be found in the CLSA Hand Grip Strength protocol Version 2.2 document [130]. As stated in the protocol[130], before starting the test, the participants were instructed: i) to sit in a proper position, with their elbow (for the dominant hand) flexed at 90 degrees; and ii) to squeeze the hand grip dynamometer to the maximum level of force possible. To minimize the impact of the number of trials on the strength, the highest value measured for the dominant hand across three trials was used in the data analysis [131,132].

3.5.2 Activity

Mobility (Dependent Variable)

Mobility, the dependent variable in the current study, was evaluated with the Timed Up-and-Go (TUG) test, an assessment tool for evaluating changes in mobility over time in older adults [28]. TUG has been validated as an assessment tool for evaluating mobility through association with gait speed (r=-0.55), Berg Balance Scale (r=-0.72) and Barthel Index of ADL (r=-0.51)[28]. This test has excellent concurrent validity (intraclass correlation coefficient, ICC= 0.88), and excellent test-retest reliability (ICC= 0.94) [133,134]. The single-task TUG was measured in the CLSA baseline data collection. According to the CLSA protocol for TUG test [135], while participants were seated in an armchair with their arm resting on the chair's arm rest, they were asked to 1) stand up from the chair, 2) walk three meters, 3) cross the mark on the floor, 4) turn around, and 5) walk back to sit on the chair. As indicated in the protocol, the participants were allowed one practice trial before the actual test[135]. Additionally, the participants were allowed to use an assistive device (e.g., cane, walker), if it was used in their normal day-to-day routine[135]. However, those who were unable to stand or rise from a chair or walk without the help of another person were excluded[135]. The length of the time (seconds) required to perform the task was recorded. TUG scores are evaluated as: "scores <10 seconds = normal; 10–19 seconds = good mobility, can go out alone, mobile without a gait aid; 20–29 seconds =

problems, cannot go outside alone, requires a gait aid; and ≥30 seconds = with increased functional dependence”[28,136].

Balance Function

Scores of the Single Leg Standing (SLS) test were extracted from the CLSA dataset to represent standing balance. Based on the CLSA protocol for measuring standing balance Version 2.1[137], the participants are instructed to stand at approximately one meter from wall with their leg in the raised position for as long as possible with a maximum of 60 seconds. The test was performed twice by each participant, one trial for each leg. For this test, the participants were not allowed to use any assistive devices (e.g., cane). However, they were allowed to practice the procedure before the test. In previous studies, reliability and validity of other variations of the SLS test (e.g., three trials of eyes open and eyes closed, using the leg of choice, max 45 seconds [138]) have been demonstrated. The CLSA SLS scores may not be comparable with other studies. However, it was informative to compare the participants within the CLSA. For each participant, the best attained SLS score (seconds) was used. Any values less than 45 seconds may indicate abnormal balance function[139].

Gait Velocity

Gait Velocity (GV), derived from the results of the CLSA Timed 4-meter Walk Test[140], was used as a descriptive variable to inform about the mobility status of the sample. According to the CLSA protocol for timed 4-meter walk test[140], the participants were allowed to use an assistive device. However, those who were unable to stand or walk without the help of another person were excluded. For GV calculation, the distance (4 meters) was divided by the time that the participant took to complete the timed 4-meter walk test (in seconds) and the outcome was reported in meters per second ($m.s^{-1}$) [141,142]. For GVs, any value below 1.0 $m.s^{-1}$ may indicate an increased risk of disability and other health outcomes [141].

Lower Extremity Strength

The score of the Chair Rise (CR) Test (s), extracted from the CLSA Baseline Dataset, was used to represent lower extremity muscle strength[136]. Based on the CLSA protocol for the CR test [143], the participants were asked to sit back in a chair with no arm rest; rise and sit back down in the chair five times as quickly as possible, with no rest in between. Accordingly, the participants were excluded if they were unable to stand or rise from a chair unassisted or if they use cane or walker regularly. In the CLSA dataset, the CR score, measured in seconds (s), was calculated as the average of the five scored trials which enables comparisons with results of other variations of functional lower limb strength assessment such as the 30-second chair sit-to-stand test[144]. Lower values indicate better performance, and, based on age groups, the normal total times for five repetitions are as follow: 11.4 seconds (60 to 69 years), 12.6 seconds (70 to 79 years), and 14.8 seconds (80 to 89 years)[145].

3.5.3 Participation

Life-Space Mobility

In the CLSA baseline dataset, "participants' mobility within their home and community" [9], over a four week period, was measured using the Life-Space Index (LSI) [9,146–148]. The LSI is a self-report measure, based on five "life-space levels" representing one's movement extending from home to outside of the home, neighborhood, town and finally outside of the town[146]. The LSI is calculated based on a total of 15 questions[146,148].

It is the sum of the scores calculated at each level by multiplying three numbers [146,148]. The LSI ranges from 0 (“totally bed-bound”) to 120 (“traveled out of town every day without assistance”), with higher scores representing higher level of travel within the household, and the community[9,146–148].

3.5.4 Personal Factors

Demographics

To describe the participant characteristics, a set of demographic variables were extracted from the CLSA baseline dataset: age, sex, sexual orientation, hearing aid use, fall history, ethnicity, country of birth, racial background, marital/partner status, household income, and education. These characteristics were collected through self-report with the use of structured/discrete categories.

Anthropometric

Anthropometric measurements including body weight, standing height and Body Mass Index (BMI) were used. According to the CLSA protocol for standing height and weight measurement [149], two measurements were collected for each variable: body weight (measured by digital physician scale in kilograms) and standing height (measured by a stadiometer to the nearest tenth of a centimeter). The average of the two measurements was used for the subsequent analyses. Body Mass Index (BMI) for each participant was calculated using the following formula: BMI = weight (kg)/height $(cm)^2$.

Frailty

The Frailty Index (FI), was used to represent frailty, a composite score calculated using variables selected from several health domains [36]. For the FI calculation, initially, all binary variables were recoded into 0 and 1 scale (“no deficit” =0; “deficit” =1), whereas interval, ordinal and continuous variables were ranked as fraction of a deficit ("Excellent" =0; "Very good" =0.25; "Good" =0.5; "Fair" =0.75 and "Poor" =1) [36, 150]. Then, for those who had missing values in less than 20% of the items, the FI was calculated by summing the deficits present in an individual and dividing the sum by the total number of deficits measured (total number of variables) for that individual[36,150]. Overall, FI scores range from 0 to 1, and are categorized as follows: i) ≤ 0.1 "Non frail", ii) 0.11 to 0.2 "Very Mild"; iii) 0.21 to 0.3 "Mild"; iv) ≥ 0.31 "Moderate/Severe" [36].

In this study, FI, calculated based on the 52 items (FI_{52}) used previously[36], was used to describe the sample, enabling comparison with previous literature. However, to reduce the multicollinearity among the explanatory variables to be included in multivariate analyses to address Objective 4, six variables were removed from the calculation, producing a 46-item FI (FI_{46}) [150]. Specifically, MAT, representing executive function, was identified as an explanatory variable for the multi-variate analysis, and therefore was excluded from the FI calculation. Likewise, self-rated hearing plus self-rated vision were excluded, given the relationships between Hearing Threshold, and Visual Acuity, respectively. In addition, walking, getting in/out of bed, and bathing were excluded due to their conceptual relationship to the TUG test and the shared similarities in movements with components of the TUG task. The remaining 46 eligible variables were used for calculating the new FI according to the standard procedures[150]. Since FI_{46} was found to be strongly correlated with FI_{52}, (r=0.987 [0.986, 0.987], p<0.001), FI_{46} was used in examining the bivariate and multivariate relationships (Objective 3 and 4).

3.6 Data Analysis

All statistical analyses were conducted using IBM SPSS Statistics Version 27. Alpha level (α) of 0.05 was used to determine statistical significance. To eliminate missing data for either correlation or regression analyses, *listwise* deletion was chosen[151]. Additionally, to only include the participants with complete data for the main variables (i.e., TUG score and HTs), those with missing values for any of these measurements were excluded from the Hypothesis testing (Objectives 2-4).

3.6.1 Descriptive Analysis

Parametric and non-parametric descriptive statistics were computed, as appropriate to the measurement scale and distribution of each variable: measures of central tendency including the mean, median, and mode, plus measures of dispersion including the standard deviation, minimum, maximum and range. The frequency and percentage were calculated for categorical variables (e.g., sex, education) and for the amount of missing data based on the total number of cases included in the study. The "Inflation" sampling weights provided by the CLSA were used to explore the representativeness of the sample statistics by estimating the values for the whole population; to compare the weighted and unweighted results, all descriptive analyses were conducted twice, with and without the sampling weights. The normality of the raw data was tested using graphical displays (e.g., histogram, P-P plot) and values of Skew/Kurtosis[151]. However, given the large sample size used for this analysis and the theory of central limit theorem, small deviations from normal distribution were not considered as violation of normality[151].

For descriptive purposes, the Hearing Threshold scores ($HT_{AllFreq}$) were summarized according to the categories of hearing loss[80], adapted to include two bins for 95-99.99 dB, and 100-105 dB. Additionally, the TUG scores were summarized according to the four categories described by Podsiadlo & Richardson (1991) [28,136]. Then, for both Hearing Threshold and TUG score, frequency analysis was conducted to describe the number of individuals within the categories, using the measures of frequency and percentage (Objective 1).

3.6.2 Hypothesis Testing

The primary purpose of this study was to examine the strength and the form of the association between $HT_{AllFreq}$ and TUG scores, after accounting for sex and age (Objective 2). The assumptions for multiple linear regression, including: 1) normality, 2) non-zero variance, 3) linearity, 4) independence, 5) homoscedasticity, and 6) no multicollinearity[151], were assessed. A correlation coefficient of $|r| > 0.7$[151] and a variance inflation factor (VIF) ≥ 10 [150] were used for detecting multicollinearity. In addition, the influence of outliers on the estimation of coefficients was investigated by looking at their effects on the slope of the regression line and the coefficients as well as the use of Cook's distance, showing no influential cases[151]. Since the necessary assumptions were met and no influential cases were found, multiple linear regression was conducted using hierarchical modeling. The independent variables were entered into the model in two steps/blocks. In the first block, the control variables, age and sex, were included. While in the second block, the main independent variable, $HT_{AllFreq}$ was added.

Designated linear bivariate relationships were examined to inform multivariate analyses, after assumptions for using correlation analyses were assessed (Objective 3).

The assumptions of Pearson's Product-Moment Correlation (i.e., normality, measurement level, no influential outlier, and linearity[151]) were satisfied for all continuous variables, except for the SLS scores which demonstrated nonnormal distribution with both ceiling and floor effects. For further analysis, this variable (SLS) was recoded as a dichotomous variable (SLS_R), 0 and 1 ("0": < 45 s, "1": 45-65 s)[139].

Therefore, to examine the bivariate relationships between TUG scores, $HT_{AllFreq}$, and the selected variables (i.e., age, sex, FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R score, and GV), correlation matrices were computed using parametric and non-parametric methods, according to the nature of the variables. The bivariate relationships between the dichotomous variables, Sex and SLS_R, with age, FI_{46}, MAT, VA, LSI, GS, CR, and GV were examined using the Spearman's correlation coefficient (2-tailed). Whereas the bivariate relationships between TUG score, $HT_{AllFreq}$, age, FI_{46}, MAT, VA, LSI, GS, CR Score, and GV were examined using the Pearson product-moment correlation coefficient (2-tailed). The magnitude of the correlation coefficients was classified as follows: 1) negligible correlation (.00 to .30), 2) low correlation (.30 to .50), 3) moderate correlation (.50 to .70), 4) high correlation (.70 to .90), and 5) very high correlation (90 to 1.00) [152].

In addition to using correlation analyses, for Objective 3, the form and strength of the relationships among these designated variables were assessed, adjusting for the effects of age and sex. Prior to conducting the regressions, the data were tested for the required assumptions, as well as for the existence of the influential cases. Since the assumptions were met and no influential case was detected, hierarchical regression analyses (i.e., multiple linear regression or logistic regression, for dependent variables that are categorical) were conducted. Hierarchical multiple linear regression was used: to examine the association of each specified variable (i.e., GV, LSI, CR, GS, SLS_R, FI_{46}, MAT and VA) with functional mobility (TUG score). Likewise, to examine the associations of Hearing Threshold ($HT_{AllFreq}$) with each specified variable, hierarchical multiple linear regression was used, with the exception that hierarchical logistic regression was used to examine the association between Hearing Threshold ($HT_{AllFreq}$) and SLS_R (a dichotomous dependent variable). For each of these analyses, age and sex were entered in the first block, and the specified independent variable in the second.

To conduct a preliminary multivariate analysis of relationships among functional mobility, hearing threshold, and other explanatory variables (Objective 4), hierarchical regression analyses were completed using six blocks of variables. A combination of methods was used to establish the explanatory variables to be included in sequential blocks. Due to their conceptual relationship to the TUG test and the shared similarities in movements with components of the TUG task, CR, GV, SLS_R, and GS were excluded from the list of explanatory variables to be included in the model. Regarding the assumptions for regression analyses, the results of Objective 3 were used to understand the collinearity across explanatory variables Age, Sex, $HT_{AllFreq}$, VA, MAT, LSI and FI_{46}; while systematic relationships were observed between the variables; as illustrated in Appendix C, none exceeded the threshold of $|r| > 0.7$[153], indicating no multicollinearity among the explanatory variables. Therefore, the selected variables were retained in the model. Additionally, all other assumptions were satisfied and there were no influential cases.

Therefore, to construct the hierarchical regression model to examine the effects of the designated additional explanatory variables on the association between HT and TUG, when controlling for age and sex, the following procedures were used. Consistent with the multiple linear regression created in Objective 2, to control for basic demographic information, the variables Age and Sex were entered in Model 1, and in Model 2, $HT_{AllFreq}$ as the main independent variable, was added. Then, VA, MAT, LSI and FI_{46} were added in the following order: Model 3) VA, to see the impact of a measure of visual function; Model 4) MAT as a measure of executive function, Model 5) LSI as a measure of ambulation in the household and travel in the community, and Model 6) FI_{46} representing a composite measure of health status.

CHAPTER 4 – RESULTS

4.1 Characteristics of the Study Sample

From the 30,097 participants included in the CLSA baseline Comprehensive cohort, for this study we included 12,646 people aged 65 to 86 years: 6,306 females (49.9%) and 6,340 males (50.1%). There was a variety of missing data among the variables, ranging from 0 (0.0%) to 2,566 (20.3%), as illustrated, for each variable, in Appendices D, E, and F. By inspection, the variable with the largest missing data was Education, with 2,566 missing values (20.3%). In regards with the main variables representing hearing and functional mobility, the HT variables had missing values ranging from 427 (3.49%) to 801 (6.76%), whereas TUG score had 262 missing values (2.11%). The weighted and unweighted descriptive statistics for all the variables are presented in Appendices D, E, and F. By inspection, in all cases, the weighted and unweighted results were consistent, therefore, the unweighted results are used here to present the findings for the study sample, rather than the weighted values estimating the values for the CLSA target population.

Descriptive statistics summarizing the sociodemographic features of the study participants, are provided in Appendices D, E, and F. As shown in Appendix D, Table D3, across the sample, by inspection Canada was the most frequently reported country of birth (n= 9,811; 77.6%); followed by the United Kingdom (n=1,005; 7.9%), the United States (n=350; 2.8%), Germany (n=173; 1.4%) and the Netherlands/Holland (n=175; 1.4%). In regards to cultural and parental ethnic background, shown in Appendix F, Table F3 and F4, 12,202 participants (95.6%) had “white” cultural background; most participants had English (n=4,960; 22.3%), Canadian (n=3,598; 16.2%), Scottish (n=2,974; 13.4%), Irish (n=2,770; 12.5%), and French (n=2,372; 10.7%) parental ethnic background. As illustrated in Appendix F, Table F1, across the sample, 12,428 participants (98.3%) identified as heterosexual, 142 participants (1.1%) as homosexual, and 39 participants (0.3%) as bisexual. For education, as shown in Appendix F, Table F2, 9,013 participants (71.2%) had post-secondary degree, certificate, or diploma. Across the sample, 811 participants (6.4%) had a total household income less than 20,000 in the past 12 months, 3,915 (31%) had $20,000 or more, but less than $50,000, while the remaining participants reported having $50,000 or more, as illustrated in Appendix F, Table F5. In regards to marital/partner status, as shown in Appendix D, Table D4, a high percentage of the sample reporting being married or living with a partner in a common-law relationship, (n= 7,870; 62.2%), while the remaining were single, never married, never lived with a partner, widowed, divorced or separated.

The summary statistics for Frailty Index, are provided in Appendix D, Table D1 and Appendix E, Table E1. As illustrated in Table D1, the sample had a mean±SD of 0.12±0.06. Across the sample, 6,435 participants (50.9%) had FI less than 0.1, while 5,133 participants (40.6%) had FI 0.11-0.2, 928 participants (7.3%) had FI 0.21-0.3, and 84 participants (0.7) had FI ≥0.31. By inspection, the average FI was higher in females compared to males (0.12 vs. 0.11). Similarly, by inspection the percentage of females in "Very Mild" (n=2,723; 43.2%), "Mild" (n=559; 8.9%), and "Moderate/Severe" (n=57; 0.9%) categories was higher than males ("Very Mild": n=2,410; 38%; "Mild": n=369; 5.8%; "Moderate/Severe": n=27; 0.4%). Additionally, the maximum FI was 0.51 in females, while it was 0.41 in males, both considered as "Moderate/Severe" [36].

Summary statistics for anthropometric variables, Height, Weight, and Body Mass Index, are provided in Appendix D, Table D1. As illustrated in Appendix D, Table D1, the sample had a mean± SD Height of 167±0.1, Weight of 77.8±16.1, and BMI of 27.9±5.0. As shown in Appendix E, Table E1, across the sample, BMI ranged from 12.9-69.6. High percentages of the sample had BMI 25-29.99 (n=5,397; 42.7%) and >30 (n=3,548; 28.1%), while the rest had either BMI less than18.5, or between18.5 and 25. By inspection, the percentage of males who were overweight was higher than females (48.3% vs. 37%), while the percentages of females in the underweight (n=84; 1.3% vs. n=22; 0.3%), normal (n=1,998; 31.7% vs. n=1,536; 24.2%), and obese (n=1,855; 29.4% vs. n=1,693; 26.7%) categories were higher compared to the males.

Appendix D, Table D1 and Appendix E, Table E1, displays the summary statistics for Visual Acuity score. According to the results, the sample had a mean±SD of 0.10±0.16 logMAR. As shown in Table E1, across the sample, 10,967 participants (86.7%) showed VA <0.3, classified as normal (intact) visual acuity, while the remaining classified as having some degree of impairment. By inspection, the number of females and males for VA <0.3 and 0.3≤ VA < 1 categories appeared to be similar, except for VA≥1 category which only consists of males.

Summary statistics for mobility-related variables, Gait Velocity, Chair Rise score, Single Leg Standing, and Hand Grip Strength are provided in Appendix D, Table D1. According to the results, the sample had a mean±SD of 0.91±0.19 for Gait Velocity, 2.87±0.85 for Chair Rise score, 26.07±22.61 for Single Leg Standing, and 31.6±10.6 for Hand Grip Strength. By inspection, males had higher averages in Gait Velocity, Single

Leg Standing, and Hand Grip Strength compared to females. While Females had higher values in Chair Rise compared to males.

Descriptive statistics for Life Space Index are illustrated in Appendix D, Table D1. According to the results, the sample had a mean±SD of 80.5±18.4 for Life Space Index. By inspection, males had higher values (mean±SD of 83.7±17.6), compared to the females (mean±SD of 77.3±18.6).

4.2 Hearing Characteristics of the Sample

Summary statistics for Self-Rated Hearing are shown in Appendix E, Table E3. Across the sample, very few (n=262; 2.1%) reported poor self-rated hearing, with the remaining reporting fair (n=1,622; 12.8%) or better self-rated hearing. By inspection, females had higher percentages in the excellent, very good, and good categories compared to the males. As shown in Appendix E, Table E2, 1346 participants (10.6%) reported the use of hearing devices, from which the majority (77.8%) used hearing aids.

The weighted and unweighted measures of central tendency and dispersion for each HT variable, the PTA results, by test frequency, for each ear are in Appendix D, Table D1. The HT scores ranged from 0 to 105 dB, except for the HT measured at 1kHz frequency for the Right Ear which had a maximum HT of 99 dB. The classification of Hearing based on the PTA results are presented in Table 4.1 and Appendix E, Table E4-6. As illustrated in Table 4.1, across the sample, 1,331 (10.5%) of the participants had $HT_{AllFreq} < 20$ dB, classified as normal (intact) hearing, while the remaining classified as having some degree of hearing loss.

Table 4.1: Hearing Threshold classifications ($HT_{Classification}$), done using $HT_{AllFreq}$.

Categories	**$HT_{AllFreq}$ (dB)**	**Males**		**Females**		**Total**	
		N (Column %)		**N (Column %)**		**N (Column %)**	
		Raw	**weighted**	**Raw**	**weighted**	**Raw**	**weighted**
Normal	<20	449 (7.1)	32,694 (6.3)	882 (14.0)	72,415 (11.6)	1,331 (10.5)	105,110 (9.2)
Mild	20-34.9	1,745 (27.5)	138,741 (26.8)	2,426 (38.5)	237,249 (38.0)	4,171 (33.0)	375,990 (32.9)
Moderate	35-49.9	2,264 (35.7)	192,031 (37.0)	1,900 (30.1)	202,255 (32.4)	4,164 (32.9)	394,286 (34.5)
Moderately Severe	50-64.9	1,331 (21.0)	105,162 (20.3)	725 (11.5)	71,470 (11.5)	2,056 (16.3)	176,632 (15.5)
Severe	65-79.9	291 (4.6)	26,869 (5.2)	138 (2.2)	13,356 (2.1)	429 (3.4)	40,225 (3.5)
Profound	80-94.9	43 (0.7)	3,529 (0.7)	22 (0.3)	1,762 (0.3)	65 (0.5)	5,291 (0.5)
	95-99.9	10 (0.2)	387 (0.1)	6 (0.1)	427 (0.1)	16 (0.1)	814 (0.1)
No Responses	105	1 (0.0)	5 (0.0)	2 (0.0)	1,103 (0.2)	3 (0.0)	1,108 (0.1)

The results of the correlation analysis between $HT_{AllFreq}$, TUG score and other designated explanatory variables are provided in Table 4.2. Age, Sex, TUG, FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV were significantly related to $HT_{AllFreq}$. The correlation coefficients ranged from -0.224 to 0.430 ($p < 0.05$).

Table 4.2: Correlation matrix output for the relationships between $HT_{AllFreq}$ and Age, Sex, TUG, FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV, (N=9099).

	Correlation Coefficient	***p*-value**	**95% CI**	
			Lower	**Upper**
HT – TUG*	0.162	<.001	0.142	0.182
HT – Age*	0.430	<.001	0.413	0.446
HT – Sex^{+}*	-0.224	<.001	-0.244	-0.204
HT – VA*	0.102	<.001	0.081	0.122
HT – MAT*	-0.111	<.001	-0.131	-0.091
HT – LSI*	-0.069	<.001	-0.090	-0.049
HT – FI_{46}*	0.161	<.001	0.141	0.181
HT – GV*	-0.135	<.001	-0.155	-0.115
HT – CR*	0.094	<.001	0.074	0.114
HT – GS*	0.057	<.001	0.036	0.077
HT – SLS_R^{+}*	-0.189	<.001	-0.209	-0.168

*Significant at 0.05 significance level.

$^{+}$ Spearman correlation.

As illustrated in Tables 4.3 – 4.5, systematic association between HT and the designated explanatory variables was also observed are controlling for Age and Sex. Specifically, when controlling for Age and Sex, HT accounted for a systematic portion of the variance of each explanatory variable (i.e., FI_{46}, MAT, VA, LSI, GS, CR, SLS_R, and GV); the regression summaries are presented in Table 4.3 and Table 4.4. Moreover, the results of the logistic regression, summarized in Table 4.5, indicate that when accounting for Age and Sex, HT made a significant contribution to the prediction of the SLS_R scores with an odd ratio of 0.986, CI 95%: [0.983-0.999], such that as the average hearing threshold (dB) increases, the odds of having SLS score above 45 seconds decrease.

Table 4.3: Model summary of the multiple linear regression analyses, examining bivariate relationships, controlling for age and sex, between $HT_{AllFreq}$ and FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV.

Model		**R**	**R^2**	**Change Statistics**				
DV	**IVs**			R^2 Change	F Change	df_1	df_2	*p*-value (F Change)
VA	AGE, SEX, HT*	.231	0.053	0.001	12.696	1	11506	<.001
MAT	AGE, SEX, HT*	.225	0.051	0.005	53.926	1	10924	<.001
LSI	AGE, SEX, HT*	.262	0.069	0.003	43.078	1	11597	<.001
FI_{46}	AGE, SEX, HT*	.332	0.110	0.007	91.747	1	11601	<.001
GV	AGE, SEX, HT*	.303	0.092	0.005	69.224	1	11618	<.001
CR	AGE, SEX, HT*	.174	0.030	0.002	27.435	1	11061	<.001
GS	AGE, SEX, HT*	.780	0.609	0.001	15.862	1	10614	<.001

*Significant at 0.05 significance level. DV=Dependent Variable; IV=Independent Variable.

Table 4.4: Summary of the coefficients for the multiple linear regression analyses, examining bivariate relationships, controlling for age and sex, between $HT_{AllFreq}$ and FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV.

Model		***b***	***t***	***p*-value**	**Standardized *b***	**95% CI for *b***	
DV	**Main IV**					**Lower Bound**	**Upper Bound**
VA	$HT_{AllFreq}$*	0.000	3.563	<.001	0.037	0.000	0.001
MAT	$HT_{AllFreq}$*	-0.047	-7.343	<.001	-0.078	-0.059	-0.034
LSI	$HT_{AllFreq}$*	-0.084	-6.563	<.001	-0.067	-0.109	-0.059
FI_{46}	$HT_{AllFreq}$*	0.000	9.578	<.001	0.096	0.000	0.001
GV	$HT_{AllFreq}$*	-0.001	-8.32	<.001	-0.084	-0.001	-0.001
CR	$HT_{AllFreq}$*	0.003	5.238	<.001	0.056	0.002	0.005
GS	$HT_{AllFreq}$*	-0.021	-3.983	<.001	-0.028	-0.031	-0.01

*Significant at 0.05 significance level. DV=Dependent Variable; IV=Independent Variable.

Table 4.5: Summary of the logistic regression for the relationship between $HT_{AllFreq}$ and SLS_R, controlling for age and sex.

Model		**B**	**Wald**	**df**	***p*-value**	**Exp(B)**	**95% CI for EXP(B)**	
							Lower	Upper
Step 1	Sex*	0.379	69.035	1	<.001	1.461	1.336	1.598
	Age*	-0.158	1071.021	1	<.001	0.854	0.846	0.862
Step 2	Sex*	0.466	97.174	1	<.001	1.593	1.452	1.748
	Age*	-0.143	774.435	1	<.001	0.866	0.858	0.875
	$HT_{AllFreq}$*	-0.014	56.780	1	<.001	0.986	0.983	0.99
Step		**-2 Log likelihood**		**Cox & Snell R Square**			**Nagelkerke R Square**	
1		11492.141		0.124			0.177	

*Significant at 0.05 significance level.

4.3 Functional Mobility of the Sample

TUG scores ranged from 2.79 to 104.06 seconds with a median of 9.91 seconds. As shown in Table 4.6, about 51% of the total sample had “normal mobility” (TUG scores <10 seconds)[28], 46% “good mobility” (TUG scores 10-19 seconds)[28]. Very few participants in the sample (approximately 1%) were classified as having “problems, cannot go outside alone, requires a gait aid” and/or “increased functional dependence” (i.e., TUG scores >20 seconds)[28]. The full set of weighted and unweighted descriptive statistics for TUG score are shown in Appendix D, Table D1.

Table 4.6: Functional mobility of the sample, classified based on TUG scores.

Categories[28]	TUG score (S)	Males		Females		Total	
		N (Column %)		N (Column %)		N (Column %)	
		Raw	**weighted**	**Raw**	**weighted**	**Raw**	**weighted**
Normal mobility	<10	3,266 (51.5)	248,660 (48.0)	3,156 (50.0)	276,625 (44.3)	6,422 (50.8)	525,286 (46.0)
Good mobility, can go out alone, mobile without a gait	10–19	2,899 (45.7)	250,176 (48.3)	2,937 (46.6)	318,802 (51.1)	5,836 (46.1)	568,978 (49.8)
Problems, cannot go outside alone, requires a gait aid	20–29	45 (0.7)	3,518 (0.7)	75 (1.2)	9,499 (1.5)	120 (0.9)	13,016 (1.1)
With increased functional dependence	≥30	11 (0.2)	1,964 (0.4)	7 (0.1)	637 (0.1)	18 (0.1)	2,601 (0.2)

The results of the correlation analysis between TUG score and other explanatory variables are provided in Table 4.7. According to the results, Age, FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV were significantly related to TUG score, with correlation coefficients ranging from -0.600 to 0.560 (p <. 0.05). A significant relationship between Sex and TUG score was not observed (*r*=.008, *p*=.419).

Table 4.7: Correlation matrix output for the relationships between TUG score and age, sex, FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV, (N=9099).

	Correlation Coefficient	***p*-value**	**95% CI**	
			Lower	**Upper**
TUG – AGE*	0.264	<.001	0.245	0.283
TUG – Sex^{+}	0.008	0.419	-0.013	0.030
TUG – VA*	0.073	<.001	0.053	0.094
TUG – MAT*	-0.160	<.001	-0.180	-0.140
TUG – LSI*	-0.162	<.001	-0.182	-0.142
TUG – FI_{46}*	0.283	<.001	0.264	0.302
TUG – GV*	-0.600	<.001	-0.613	-0.586
TUG – CR*	0.560	<.001	0.546	0.574
TUG – GS*	-0.166	<.001	-0.186	-0.146
TUG – SLS_R $^{+}$*	-0.252	<.001	-0.272	-0.233

*Significant at 0.05 significance level.

The statistics for the regression analyses are presented in Table 4.8 and 4.9. According to the results, VA, GV, LSI, CR score, GS, FI_{46}, MAT, and SLS_R had significant contribution to TUG scores, when controlling for Age and Sex. Between these variables, GV, CR, and FI_{46} explained the most variations in TUG score (GV: 34%, CR: 28.1%, and FI_{46}:8.5%).

Table 4.8: Model summary of the multiple linear regression analyses, examining bivariate relationships, controlling for age and sex, between TUG score and FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV.

Model		**R**	**R^2**	**Change Statistics**				
DV	**IVs**			**R^2 Change**	**F Change**	**df_1**	**df_2**	***p*-value (F Change)**
TUG	AGE, SEX, VA*	.278	0.077	0.002	24.415	1	11506	<.001
TUG	AGE, SEX, MAT*	.303	0.092	0.016	191.936	1	10924	<.001
TUG	AGE, SEX, LSI*	.363	0.132	0.056	746.709	1	11597	<.001
TUG	AGE, SEX, FI_{46}*	.400	0.160	0.085	1172.081	1	11601	<.001
TUG	AGE, SEX, GV*	.649	0.421	0.345	6920.917	1	11618	<.001
TUG	AGE, SEX, CR*	.599	0.359	0.281	4847.99	1	11061	<.001
TUG	AGE, SEX, GS*	.319	0.101	0.029	337.711	1	10614	<.001
TUG	AGE, SEX, SLS_R*	.311	0.097	0.022	261.692	1	10718	<.001

*Significant at 0.05 significance level. DV=Dependent Variable; IV=Independent Variable.

Table 4.9: Summary of the coefficients for the multiple linear regressions, examining bivariate relationships, controlling for age and sex, between TUG score and FI_{46}, MAT, VA, LSI, GS, CR Score, SLS_R, and GV.

Model		***b***	***t***	***p*-value**	**Standardized *b***	**95% CI for *b***	
DV	**Main IV**					**Lower Bound**	**Upper Bound**
TUG	VA*	0.823	4.941	<.001	0.045	0.496	1.149
TUG	MAT*	-0.043	-13.854	<.001	-0.129	-0.049	-0.037
TUG	LSI*	-0.039	-27.326	<.001	-0.245	-0.042	-0.036
TUG	FI_{46}*	13.759	34.236	<.001	0.308	12.971	14.547
TUG	GV*	-8.788	-83.192	<.001	-0.615	-8.995	-8.581
TUG	CR*	1.456	69.628	<.001	0.538	1.415	1.497
TUG	GS*	-0.072	-18.377	<.001	-0.27	-0.079	-0.064
TUG	SLS_R*	-0.777	-16.177	<.001	-0.158	-0.871	-0.683

*Significant at 0.05 significance level. DV=Dependent Variable; IV=Independent Variable.

4.4 The Relationship between Hearing Threshold and Functional Mobility

The regression model used to examine the relationship between TUG and HT, controlling for Age and Sex, is summarized in Table 4.10 and 4.11. The overall model explained approximately 8.1% of the variance in TUG score ($F_{(3,\ 11629)} = 339.9$, $p < .001$). As illustrated in Table 4.10, $HT_{AllFreq}$ contributed .5% of the variance after controlling for Age and Sex. According to the results, there was a significant positive relationship between Hearing Threshold and TUG score; b=.015, 95% CI [.011, .019], $t_{(11629)=}7.57$, p<0.001, where individuals with poorer hearing had poorer functional mobility. Figure 4.1 illustrates the scatterplot of TUG score (s) as a function of $HT_{AllFreq}$ (dB).

Table 4.10: The model summary for the relationship between TUG score and $HT_{AllFreq}$, when controlling for age and sex.

Model		**R**	**R^2**	**Change Statistics**				
				R^2 Change	F Change	df_1	df_2	*p*-value (F Change)
1	Sex, Age *	.276	0.076	0.076	478.752	2	11627	<.001
2	Sex, Age, $HT_{AllFreq}$*	.284	0.081	0.005	57.336	1	11626	<.001

*Significant at 0.05 significance level.

Table 4.11: Coefficients for the relationship between TUG score and $HT_{AllFreq}$, when controlling for age and sex.

Model		***b***	**95% CI for B**		***Standardized b***	***t***	***p*-value**
			Lower Bound	Upper Bound			
1	Sex*	0.22	0.121	0.319	0.039	4.343	<.001
	Age*	0.137	0.129	0.146	0.273	30.671	<.001
2	Sex*	0.31	0.208	0.412	0.055	5.973	<.001
	Age*	0.12	0.111	0.13	0.24	24.073	<.001
	$HT_{AllFreq}$*	0.015	0.011	0.019	0.077	7.572	<.001

*Significant at 0.05 significance level.

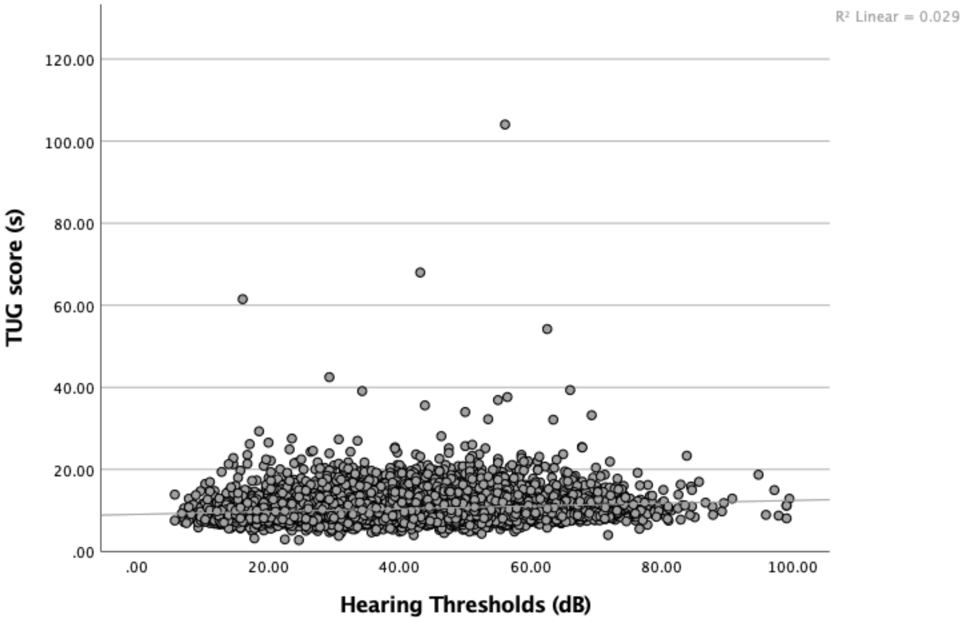

Figure 4.1: TUG score (s) as a function of Hearing Threshold ($HT_{AllFreq}$) (dB), statistics performed by simple linear regression.

4.5 The Relationship between Hearing Threshold and Functional Mobility in the Context of Other Explanatory Variables

The summary of the multiple linear regression analysis is reported in Table 4.12-4.14. According to the results, at the final stage of the hierarchical model, Age, Sex, $HT_{AllFreq}$, MAT, LSI and FI_{46} made a significant contribution to the model ($F_{(7,10771)}$=365.04, p<0.001), and accounted for 19.2% of the variation in TUG scores. After adding FI_{46} to model 6, VA no longer made a significant contribution to functional mobility (b=.305, 95% CI [-0.01, 0.621], $t_{(10771)}$=1.89, p=.058).

Table 4.12: The model summary for the multiple linear regression with TUG score as the dependent variable and $HT_{AllFreq}$, VA, MAT, LSI and FI_{46} as the main explanatory variables, controlling for age and sex.

Models	**R**	**R^2**	**Change Statistics**				
			R^2 Change	F Change	df_1	df_2	p-value (F Change)
1: Age, sex*	.275	.075	.075	439.184	2	10776	<.001
2: Age, sex, HT*	.283	.080	.005	54.059	1	10775	<.001
3: Age, sex, HT, VA*	.285	.081	.002	17.599	1	10774	<.001
4: Age, sex, HT, VA, MAT*	.309	.095	.014	163.366	1	10773	<.001
5: Age, sex, HT, VA, MAT, LSI*	.376	.142	.047	583.99	1	10772	<.001
6: Age, sex, HT, VA, MAT, LSI, FI_{46}*	.438	.192	.050	666.327	1	10771	<.001

*Significant at 0.05 significance level.

Table 4.13: ANOVA table Summary for the multiple linear regression with TUG score as the dependent variable and $HT_{AllFreq}$, VA, MAT, LSI and FI_{46} as the main explanatory variables, controlling for age and sex.

Model	**df_1**	**df_2**	***F***	***p*-value**
1: Age, sex*	2	10776	439.184	<.001
2: Age, sex, HT*	3	10775	312.408	<.001
3: Age, sex, HT, VA*	4	10774	239.068	<.001
4: Age, sex, HT, VA, MAT*	5	10773	226.768	<.001
5: Age, sex, HT, VA, MAT, LSI*	6	10772	296.515	<.001
6: Age, sex, HT, VA, MAT, LSI, FI_{46}*	7	10771	365.036	<.001

*Significant at 0.05 significance level.

Table 4.14: Summary of the coefficients for the multiple linear regression with TUG score as the dependent variable and $HT_{AllFreq}$, VA, MAT, LSI and FI_{46} as the main explanatory variables, controlling for age and sex.

Model		***b***	**95% CI for *b***		**Standardized *b***	***t***	***p*-value**
			Lower Bound	**Upper Bound**			
1	Sex*	0.208	0.106	0.311	0.037	3.978	<.001
	Age*	0.136	0.127	0.146	0.272	29.388	<.001
2	Sex*	0.298	0.193	0.403	0.053	5.556	<.001
	Age*	0.119	0.109	0.13	0.238	23.014	<.001
	$HT_{AllFreq}$*	0.015	0.011	0.019	0.078	7.353	<.001
3	Sex*	0.285	0.18	0.39	0.05	5.315	<.001
	Age*	0.115	0.105	0.126	0.23	21.854	<.001
	$HT_{AllFreq}$*	0.015	0.011	0.019	0.076	7.219	<.001
	VA*	0.718	0.382	1.053	0.04	4.195	<.001
4	Sex*	0.21	0.105	0.315	0.037	3.92	<.001
	Age*	0.106	0.096	0.117	0.212	20.133	<.001
	$HT_{AllFreq}$*	0.013	0.009	0.017	0.067	6.359	<.001
	VA*	0.621	0.288	0.954	0.034	3.653	<.001
	MAT*	-0.04	-0.046	-0.034	-0.12	-12.781	<.001
5	Sex	-0.011	-0.115	0.093	-0.002	-0.213	0.831
	Age*	0.091	0.081	0.101	0.181	17.517	<.001
	$HT_{AllFreq}$*	0.011	0.007	0.015	0.055	5.378	<.001
	VA*	0.520	0.195	0.845	0.029	3.139	0.002
	MAT*	-0.033	-0.039	-0.027	-0.099	-10.749	<.001
	LSI*	-0.036	-0.038	-0.033	-0.224	-24.166	<.001
6	Sex*	-0.127	-0.228	-0.026	-0.022	-2.455	0.014
	Age*	0.066	0.055	0.076	0.131	12.78	<.001
	$HT_{AllFreq}$*	0.008	0.004	0.012	0.039	3.912	<.001
	VA	0.305	-0.01	0.621	0.017	1.897	0.058
	MAT*	-0.024	-0.03	-0.019	-0.074	-8.213	<.001
	LSI*	-0.028	-0.031	-0.025	-0.175	-18.984	<.001
	FI_{46}*	11.031	10.194	11.869	0.245	25.813	<.001

*Significant at 0.05 significance level.

CHAPTER 5 – DISCUSSION AND CONCLUSION

According to previous research, mobility limitations, hearing loss and their common comorbidities are highly prevalent in older adults[12], often affecting their overall health[12]. However, there are inconsistencies and gaps in the knowledge of the relationship between hearing and functional mobility, especially in the context of various physiological and personal factors that are related to hearing and/or mobility[103,106].

This cross-sectional, descriptive study, with 12,646 participants between the ages of 65 to 86 years, has been done using the CLSA baseline Comprehensive Cohort with the primary purpose of exploring the relationship between Functional Mobility and Hearing Threshold among older Canadians. The secondary purpose was to examine the relationship between functional mobility and hearing threshold in consideration of a set of other critical physiological and personal factors that could influence the relationship between hearing and functional mobility. In the following sections, we discuss the key characteristics of the study sample, the methods, the answers to the research questions obtained, and the implications for future work.

5.1 Characteristics of the Study Sample

5.1.1 Social Determinants of Health

Similar to the trends observed for the whole CLSA cohort (aged 45- 85 years) [114], the participants in this study often reported positive determinants of health: high levels of education, high household income, and being Canadian born. In addition, many reported being in the majority in terms of sexual orientation, and having a white cultural background, both reducing their risk of health inequities as a function of their sexual and cultural identities. Overall, the study sample exhibited positive socioeconomic determinants of health, yet some individuals demonstrated vulnerability to health inequities based on factors such education, economic status, and marginalization due to race/culture and sexual orientation.

5.1.2 Biological Determinants of Health

The study cohort contained community dwelling older adults who were characterized by some biological factors that are considered as positive for health, and some had biological factors that threaten health. For instance, the sample were not cognitively impaired at the time of recruitment, and during baseline assessments many showed intact executive function. Many participants had no visual acuity impairment, many demonstrated the ability to move out of the neighborhood independently[154,155], and most were not classified as frail[156]. However, consistent with the trends previously reported for the whole cohort[36,157], many people included in this study were overweight or obese. Some had impaired executive function, a few were frail, and some had limited amount of movement through their community. On the whole, among the study sample, many exhibited positive biological determinants of health, yet some demonstrated characteristics that limit their overall health and function.

5.1.2 Hearing

Hearing varied depending on the evaluation method used. According to the results of self-rated hearing, many participants rated their hearing as excellent, very good, and good. However, according to the results of Pure-Tone Audiometry, the primary measure of hearing, consistent with the previous report[117], the sample showed various levels of hearing loss. As expected, given the age range within the study sample, many participants showed high-frequency hearing loss. Some also had hearing loss in the speech-frequency range, and a few had hearing loss in the low-frequency ranges. Mick et al. (2020), used PTA to describe the prevalence of hearing loss in adults 45 to 85 years of age using the CLSA baseline Comprehensive dataset [117]; despite the differences in Hearing Threshold calculations, the range of frequencies used, and the participants' age range, the proportions reported proportions by Mick and colleagues (2020) were consistent with our the findings from the older cohort included in this study[117].

In this study, according to the average hearing thresholds measured using all frequencies, while some participants had intact hearing, the majority (approximately 85%) had mild, moderate, or moderately severe hearing loss, and a few had severe and profound hearing loss. According to the results of PTA, within the sample many have hearing loss, while for self-rated hearing, only a few rated their hearing as fair or poor, a difference in findings that could be due to the lack of ability to self-identify the presence of hearing loss. Overall, the use of self-rated hearing to capture the participant's auditory perception, combined with PTA which provides the true hearing threshold levels, was beneficial in documenting the hearing status of the sample.

Hearing loss was associated with all the contextual and biological factors that were assessed. Age and sex had the strongest associations with hearing loss. Moreover, when age and sex were held constant, hearing loss still had a systematic association with impairments in visual acuity, executive function, balance, upper and lower extremity strength, and gait velocity. Likewise, systematic relationships between hearing loss and life space mobility were such that as hearing loss increased, restriction in community mobility and household ambulation also increased, with possible related decreased physical activity and/or increased social isolation[158–160]. In addition, similar to other factors, a systematic association was found between hearing loss and frailty levels, in a way that more severe hearing loss was associated with more severe frailty levels. Overall, hearing loss was common in this group of older adults, and it was associated with several negative health consequences, as previously reported in the literature[26,81–89].

5.1.3 Mobility

The TUG test was chosen as the primary measure of Functional Mobility. In contrast to Gait Velocity or Life Space Index that relate to aspects of mobility, the TUG test includes key elements of basic daily mobility tasks (i.e., chair transfers, level walking, turning), and it is validated in terms of screening for independent mobility[28]. When considering the results of the TUG test, the sample in this study showed diverse characteristics. The scores were varied across the spectrum: some people showed mobility classified as "independent for basic transfers"[28], whereas others showed poorer functional mobility and increased functional dependence. There were cases at both ends of the spectrum. For the same target population, these findings were consistent with previous studies[161]. The range of scores not only reinforces the diversity in functional mobility present in the sample, and a broad sector of older Canadians; it is also favourable for examining relationships among functional mobility and other variables.

Muscle strength, balance skills, and gait velocity also varied within the study sample. Regarding the Upper Extremity Strength, on average the participants had normal hand grip strength, with males having higher values compared to females. For Lower Extremity Muscle Strength (CR test), average scores were close to the reference values[145,162], indicating on average normal Lower Extremity Strength, but with wide variation such that some individuals demonstrated low muscle strength as illustrated by the maximum CR of 12.3 seconds for males, and 25.8 seconds for females. Both ceiling and floor effects were observed for the test of standing balance, the SLS test, with clusters of scores around both the upper and lower score limits; therefore, many participants had either poor or good balance function, while some scores were within the mid-range. The participants performance on 4-meter walk test demonstrated a gait velocity that is consistent with previous report in older adults[162], with females having a slightly lower Gait Velocity compared to the males. In summary, acknowledging the sex differences in the findings, the scores on muscle strength, balance skills, and gait velocity were varied, and the observed values were consistent with previous literature about older adults[162].

Functional mobility was associated with all the contextual and biological factors that were assessed, except sex. Higher chronological age was associated with worsening functional mobility, and when age and sex were controlled, poor functional mobility still had systematic association with impairments in visual acuity, executive function, balance, upper and lower extremity strength, gait velocity, and life space mobility. Gait velocity and lower extremity strength had the strongest associations with functional mobility. Similarly, frailty levels had systematic association with functional mobility, such that poorer functional mobility was associated with being frailer. In summary, the sample varied in terms of the mobility scores. The presence of impaired functional mobility was associated with critical factors that contribute to mobility and health. Therefore, the observed trends are consistent with previous literature[22].

5.2 Relationship between Hearing and Functional Mobility

The primary purpose of this study was to explore the relationship among Functional mobility and Hearing Threshold. Hierarchical multiple linear regression allowed for examining the effect of Hearing Threshold on Functional Mobility, independent of the influence of covariates, Age and Sex. According to the results, when controlling for age and sex, hearing made a small but significant contribution to the variance in Functional Mobility. Specifically, introducing hearing to the model increased the explained variance in functional mobility by 0.5% to a total of only 8.1%. When the effect of Age and Sex were held constant, for every 1 dB increase in Hearing Threshold, TUG score increased by 0.015 seconds. Therefore, the specific hypothesis for this objective was supported, indicating a small, positive relationship between Hearing Threshold (dB), measured by PTA, and Functional Mobility, measured by TUG test.

The observed findings add to the evidence obtained from previously reported exploratory studies. Previous exploratory studies resulted in mixed findings, but were also limited by methodological factors including the selected measure of hearing status[106], and/or small sample size[103]. One strength of this work relative to previous studies, is the use of a valid and reliable measure of hearing, Pure-Tone Audiometry Hearing Threshold, relative to previous exploratory studies that used self-reported measures[106]. Another strength is the use of a large population with variations in both hearing and functional mobility, since it is important to consider that in studies with small sample size or little variations in participants' characteristics, the chance of detecting the true association is reduced[103]. Overall, the approach used in this work relative to previous studies helps to address the gaps in the previous literature through use of valid and reliable measures of Hearing Threshold and Functional Mobility, with a large Canadian sample.

5.3 The Relationship Between Functional Mobility and Hearing: The Results of Multi-Variate Analysis

The secondary purpose of this study was to conduct a preliminary investigation of the multi-variate relationships that influence mobility. The ICF framework posed some strengths and some challenges as a guide for this work. It was challenging to classify a particular tool that addressed multiple constructs into one domain. For instance, the Chair Rise Task, considered a measure of lower body muscle strength, could be classified within Body Function and Structures domain, but rising to stand from a seated position, and sitting down are basic functional movements that are typically classified in the Activity domain. On the other hand, the ICF domains allowed the ability to differentiate variables that tap into similar concepts but in different ways[163]. For instance, Gait Velocity and Life Space Index relate to mobility, but address different aspects of mobility; gait velocity measured with four-meter walk test can be classified within the Activity domain, while Life Space Index, as an indicator of mobility in the community, is more related to participation. The CLSA dataset had the relevant variables to explore the research question.

To build a parsimonious model, a discrete number of variables were chosen for the hierarchical regression analyses conducted to examine multivariate relationship related to hearing and mobility: Visual Acuity, to recognize the importance of vision as a source of sensory input for controlling balance and mobility; Executive Function, to consider the importance of cognition; Life Space Mobility, as an indicator of engagement in the community; and Frailty, as a composite score of general health. Hierarchical regression modeling enabled examination of the strength and direction of the relationships and provided insight into other factors influencing the observed relationship between hearing and mobility. Overall, hierarchical regression modeling, aside from being easy to work with[164], is based on theory testing, and gives insight into the contribution of new variable(s) to the outcome, when known variables are held constant[151]. The final model accounted for 19.2% of the variance in Functional Mobility, an increase of 11.3% over the variance explained by Hearing when adjusting for age and sex, as discussed in section 5.2 above. The specific contribution of the designated variables is discussed below.

Introducing Visual Acuity to the model added a systematic contribution to the observed relationship between Hearing Threshold and Functional Mobility. According to the results of the multiple linear regression, adding Visual Acuity improved the previous model by 0.2%, yet the contribution of hearing remined significant and unchanged. Specifically, as hearing and visual acuity worsened, functional mobility also worsened. While Mick et al., (2020), reported prevalence of dual visual and hearing impairment within the CLSA baseline comprehensive cohort[117], the small but systematic contribution of Visual Acuity observed in this study provides insight into potential impact of having combined visual and hearing impairments on Functional mobility.

The model was also improved after including Executive Function. It accounted for 1.4% of the variation in Functional mobility. The addition of Executive Function produced a small reduction in the regression coefficients for both Hearing Threshold and Visual Acuity, and each variable explained a systematic portion of the variance in

Functional mobility. According to the findings, as Executive Function worsened, Functional Mobility also declined. Therefore, the proposed theory linking cognitive function and/or cognitive demand with hearing and mobility, was supported[94].

After adding Life Space Mobility to the model, the model improved by 4.7%. Though more variation in Functional Mobility was explained by this model, the contribution of each of Hearing Threshold, Visual Acuity, and Executive Function to Functional Mobility was reduced, but remained significant. The observed findings indicate that impairments in hearing and visual acuity, as well as restricted ambulation in household and community is associated with poor functional mobility. Therefore, the theory that life space mobility, as a general indicator of ambulation in the community, would provide unique contributions to the variance in functional mobility, was supported. Ultimately, the observed findings supported the proposed theories linking physical activity, as well as social isolation to hearing and mobility.

Finally, introducing frailty, a composite measure reflecting overall health status, added the highest contribution to the overall model. It explained an additional 5% of the variation in Functional Mobility. After adding Frailty, the contribution of the Visual Acuity became insignificant, while Hearing Threshold, Executive Function, and Life Space Mobility each continued to explain a unique, but smaller portion of the variance in mobility. As the number of health deficits accumulated, Functional Mobility declined as expected. Therefore, the benefit of including Frailty as a composite score of overall health status in studying the relationship between hearing and mobility, was supported.

As previously described, functional mobility is a complex skill, influenced by multiple interrelated factors[22]. The results of the hierarchical multiple regression supported the research hypothesis that a significant portion of Functional Mobility variation is explained by Hearing Threshold, Executive Function, Life-Space Mobility, and Frailty, when the effect of Age and Sex are held constant. Therefore, studying the relationship between Hearing and Functional Mobility in isolation, is likely to overestimate the strength of the association.

5.4 Limitations

Several limitations to this research stem from the cross-sectional, secondary research design. The CLSA data sharing agreement provided access to the baseline dataset, allowing examination of relationships among variables using the cross-sectional design. Project timelines did not permit application for access to follow-up datasets; therefore, longitudinal analyses which offer opportunity to probe cause: effect relationships were not possible.

As a secondary analysis, the variables available to be included in the study, and the protocols for data collection, were predetermined by CLSA. While the variables chosen have properties that merit their use to address the current research objectives, in some cases, the method selected also posed limitations with respect to measuring the construct of interest. For example, the Chair Rise task provides a composite score of lower limb muscle strength, but does not permit measurement of specific muscle groups, in units of muscle torque. The TUG test, the dependent variable in this study, is a validated measure of functional mobility, but according to the validated, CLSA protocol[135], participants can use devices that they use regularly, including hearing aids, during the test; therefore, the effects of hearing loss, detected through PTA, on functional mobility may have been mitigated by the use of hearing aids during the collection of the

TUG test data. Moreover, the TUG test included in the CLSA baseline dataset does not include a specific challenge to hearing or cognition; had the dual-task TUG been included in the CLSA dataset, better examination of the relationships among hearing, cognition and mobility would have been possible

One limitation of this secondary analysis comes from the absence of some constructs of interest in the CLSA baseline dataset. For instance, physical activity level, as a critical factor in studying hearing and mobility, is not included in the baseline dataset. Hearing Handicap Inventory for the Elderly (HRG) is another factor that could capture the psychological and social effects of hearing loss[165], but it is not present in the baseline dataset. Furthermore, measures that capture sensori-integration for balance, reactive balance, and dual-task balance control are not included in the CLSA dataset. The absence of these factors poses some limitations for this research in testing the relevant relationships, and the proposed theories linking hearing and mobility.

Another limitation stemming from the use of secondary analysis relates to the recruitment procedures of the CLSA. Individuals living in long-term care institutions, or those with cognitive impairment were excluded from the whole CLSA cohort. The presence of these individuals in our study would help in clarifying the nature of the association between hearing and mobility, particularly with respect to the influence of cognitive impairment on the relationship. In addition, only a small proportion of people who participated in the CLSA are from under-represented groups, and/or people who live in rural areas; given the adverse effects of health disparities on people, having a higher proportion of people from these groups and communities would increase the external validity of the findings.

Other limitations relate to the hierarchical regression analyses that were used to examine complex, multi-variate relationships. The sample size was large, and missing data were addressed through *listwise* exclusion, which can lead to biased results due to loss of information. The hierarchical models that were developed were designed for examining the strength of the association and the unique contributions in multivariate analyses, but are limited in examining latent measures, as well as cause: effect relationships within a cross-sectional study. In addition, the designated set of variables, and the order in which they were entered in the model, were determined based on theory, to provide a preliminary examination of the relationships between functional mobility, hearing and relevant contextual factors; while the variables selected capture a set of relevant contextual factors from some domains of the ICF framework, a complete set of factors was not incorporated in this preliminary multi-variate analysis, so some relevant relationships have yet to be explored.

5.5 Implications and Conclusion

The current descriptive study, conducted using the CLSA baseline Comprehensive Cohort, included a sample of older adults, representative of the general Canadian population for those communities included in the research. Social and biological determinants of health, Hearing, and Functional Mobility status each varied across the sample. The primary purpose of this study was to explore the relationship between Hearing, measured by PTA, and Functional Mobility, measured by TUG test. When accounting for Age and Sex, Hearing Threshold had a small but significant contribution to Functional Mobility, explaining 0.5% of the variance. As the secondary purpose, the observed relationship between Hearing and Functional Mobility was examined in the context of other factors including Vision, Executive Function, Life Space Mobility, and Frailty levels. According to the results of the hierarchical multiple linear regression, after controlling for Age and Sex, Hearing Threshold, Executive Function, Life Space Mobility, and Frailty levels had systematic contributions to Functional mobility, explaining a total variance of 19.2%. The findings expand the literature regarding the hearing and mobility of older Canadians, and illustrate the value of examining the relationship between hearing and functional mobility in consideration of the other variables which relate to hearing, mobility and health. These results also inform further research, including the following examples.

Exploring more variables in future exploratory research is needed to probe all the ICF domains and to build a more comprehensive analysis of the factors that could influence the effect of hearing on mobility. For instance, to elaborate on the construct of cognitive impairment to assess the proposed theory linking hearing and mobility through cognition, future research can draw on more variables included in the CLSA baseline dataset to capture more elements of cognitive function such as psychomotor speed or memory. Likewise, to better assess vision, and better examine integration among vision and hearing future research can include variables that capture more elements of visual function such as depth perception and peripheral visual fields. In addition, including other variables to specifically identify medical diagnoses such as diabetes, cardiovascular diseases with an indication of disease severity, is recommended to obtain better understanding of the impact of these diseases on the relationship among hearing and mobility. Including physical activity in the analysis will allow differentiation of impairments that arise due to inactivity from those that are caused by aging. Likewise, including a measure of hearing handicap in the analysis, which is available within the first follow-up, will provide insight into the impairments in communication and social interaction that arise due to hearing loss. Lastly, to account for major impacts of social factors, in future research, including variables that capture social of determinants of health such as education, income, cultural/ethnic background, and sexual orientation will be valuable. Drawing on opportunities to expand the variables available from within the CLSA datasets, will be beneficial in future research designed to examine multi-variate analysis of the relationships that influence the association between hearing and mobility.

To further understand the mechanisms underlying the relationship between hearing and mobility, conducting new research with experimental designs is needed. For instance, including other measures of mobility that capture all elements of routine mobility tasks such as a mobility task that requires dual-task challenges involving hearing demands and/or cognitive demands should be considered to further explore the relationship between hearing, cognition, and mobility. In addition, with experimental designs, manipulation of sensory systems can be included. For instance, specific challenges of sensorimotor control of balance and mobility should be considered. Manipulating sound sources in a room as a potential tool to inform orientation in space, and/or providing temporal auditory cues with the intent to regulate balance during walking, can be considered in examining the self-motion perception theory in people with intact hearing and those with impaired hearing. Moreover, imposing hearing demands in the presence or absence of visual and/or somatosensory inputs can be done to investigate sensory integration of hearing, vision, vestibular, and somatosensory inputs for balance and mobility, and to test for differential effects on people with hearing loss in comparison to those with intact hearing. In addition to the paradigms that use voluntary movements, studying these relationships and understanding if hearing loss would impact reactive control strategies would also be helpful. Therefore, these types of studies using experimental designs allow the manipulation of variables to test theories about the relationship between hearing and mobility, and improve understanding of the cause: effect relationships.

To further explore the factors influencing the relationship between hearing and mobility, conducting new research with dataset(s) that include constructs corresponding to different ICF domains is also needed. For instance, from Body Function and Structure domain, including measures such as vestibular and somatosensory impairments that provide insight into the important systems involved in body movements are valuable in studying hearing and mobility. Having the opportunity to conduct new research with the relevant constructs from any of these domains will be beneficial in future research to determine if the nature of the relationship among hearing and mobility is influenced by any of these factors.

To extend external validity, new research should recruit participants with diverse characteristics. For instance, future research should recruit participants who are Indigenous, members of visible minority groups, live in rural communities and/or have impaired mobility. Expanding the sample characteristics will be beneficial in supporting the internal and external validity of the results.

The relationship between hearing and mobility can be further analyzed with the use of other statistical methods. For instance, further investigation of the relationship between hearing and mobility in people with impaired mobility can done using different statistical modeling methods either within a cross-sectional design (e.g., analysis of a subset of the data including those with some degree of mobility impairment) or a longitudinal design (e.g., examining the changes in hearing status on changes in mobility status). Moreover, examining the causal relationships and mediating effects would allow for more in-depth understanding of the true associations and underlying mechanisms. Though the hierarchical regression modeling allowed us to account for the observed measures/variables, other statistical methods such as structural equation modeling (SEM) and Principal Component Analysis (PCA) can extend this work. An advantage of SEM is that it can be informative for more complex relationships, including models with multiple mediators[151,164]. Also, PCA allows examining clusters of variables. For example, the effect of Hearing Threshold on Functional Mobility may operate partially or completely through mediating factors or through interactions between either determinants of health, and/or disease diagnoses, that influence the relationship between hearing and mobility. The use of different statistical methods will provide the opportunity in future research to determine the mechanisms underlying the relationship between hearing and mobility.

In conclusion, this exploratory, cross-sectional, secondary research design has added to the current evidence on the relationship between hearing and functional mobility by addressing some of the gaps identified in the previous studies. A systematic, but small association between hearing and functional mobility was observed; when controlling for age, sex, and relevant factors related to vision, cognition, muscle strength, frailty and life space mobility, the unique contribution of hearing to variance in functional mobility remained. The study also gives insight into future research to examine the relationship between hearing and mobility, and ultimately, to inform health policies and practices related to hearing and mobility that affect healthy aging.

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APPENDIX A: A Summary of the Studies Considered in the Literature Review

Study		**Mikkola et al. (2015)**	**Bang et al. (2019)**
Design		Exploratory, cohort, cross-sectional, prospective	Exploratory, cohort, cross-sectional, prospective
Participants (N)		848	3864
Incl./ Excl		**Excl.** N/A **Incl.** living: 1) independently, 2) in the recruitment area; being able to communicate; willingness to participate	**Excl.** N/A **Incl.** N/A
Sample Characteristics		-366 adults aged 80±6.9 (good hearing) -393 adults aged 81±7.4 (some hearing problems) -88 adults aged 83±6.6 (major hearing problems)	3864 adults aged 40 years and older -2135 females, 1729 males
Participants' Characteristics	Hearing	self-reported questionnaire	PTA, each ear at 0.5, 1, 2, and 3 kHz
	Cognitive	MMSE	N/A
	Balance/ mobility	Functional Ability: 14-item self-report (5 ADL and 9 IADL), Perceived Mobility: Level of difficulty of four mobility tasks.	N/A
	Physical Activity	N/A	N/A
Single-/Dual-task model		**Mobility task:** SPPB test	**Mobility task:** Postural Instability in firm/foam x eyes open/ closed
Mobility Task Type		Standing: Standing balance (SPPB), Chair stand test (SPPB) Perturb Standing N/A Walking: Walking speed (SPPB)	Standing Postural Instability Perturb Standing N/A Walking N/A
Dependent Variable		**Balance control/ adjustment** Kinematics: GV, SLS, CR	**Balance control/ adjustment** Kinematics Postural instability
		Cognitive task performance N/A	**Cognitive task performance** N/A
		Brain Activations N/A	**Brain Activations** N/A
		Dual-tasks costs N/A	**Dual-tasks costs** N/A
Primary outcome of interest		Major hearing problem slower GV, longer CR time, less likelihood of a higher balance score, sig. more ADL and IADL difficulties; Inc in level of difficulty % as HL increase	From 127: bilateral moderate HL=11.8%, unilateral moderate HL=6.5%, one mild and the other moderate HL= 8.8.%, Severe= 12.2 %, profound HL = 11.9%"

Study		**Rosso et al. (2017)**	**Plummer-D'Amato et al. (2011)**
Design		Exploratory, cohort, cross-sectional, prospective	Exploratory, cohort, cross-sectional, prospective
Participants (N)		16	44
Incl./ Excl		**Excl.** Balance, neurologic abnormalities, and cognitive impairment that influences balance and mobility. **Incl.** N/A	**Excl.** A history of: (a) >2 falls in the last 12 months, (b) acute medical illnesses (c) neurological disorders (d) any major orthopedic disorders affecting walking. **Incl.** Ability to walk cont. for 1 min, score >23 on MMSE, and no impairments affecting hearing and respond verbally to auditory stimuli
Sample Characteristics		6 YA (age: 22–30) 10 OA (age: 66–81)	23 YA (age: 18-30) 21 OA (age: >65)
Participants' Characteristics	Hearing	N/A	N/A
	Cognitive	N/A	MMSE
	Balance/ mobility	N/A	TUG, 5-m walk test
	Physical Activity	N/A	N/A
Single-/Dual-task model		**Mobility task:** Posturography **Cognitive task:** Auditory CRT Task	**Mobility task:** Walking **Cognitive task:** Auditory Stroop Task or Speech
Mobility Task Type		<u>Perturb Standing</u> Dynamic Post. <u>Walking</u> N/A	<u>Perturb Standing</u> N/A <u>Walking</u> walked for 60 sec
Dependent Variable		**Balance control/ adjustment** <u>Kinetics:</u> MAD of the COM translation of the low back sensor in the AP direction	**Balance control/ adjustment** <u>Kinematics</u> Gait speed, stride duration, DLS duration, and temporal gait symmetry
		Cognitive task performance Auditory CRT Task: Response time	**Cognitive task performance** Accuracy: % Correct Performance
		Brain Activations FNIRS changes in oxyhemoglobin	**Brain Activations** N/A
		Dual-tasks costs N/A	**Dual-tasks costs** % change between faster and slower
Primary outcome of interest		Reduction: <u>For OA</u>: Postural → 59%, CRT → 7.3% <u>For YA</u>: Postural → 75%, CRT → 10%	A significant Age x Task interaction on gait speed, [F(3,40) = 2.95, p < 0.05]

Study		**Bruce et al. (2019)**	**Lau et al. (2016)**
Design		Exploratory, cohort, cross-sectional, prospective	Exploratory, cohort, cross-sectional, prospective
Participants (N)		87	16
Incl./ Excl		**Excl.** Conditions and medications affecting cognitive or balance; MoCA ≥26/30; hearing aid use; difficulties in balance or mobility. **Incl.** N/A	**Excl.** Interaural differences >15 dB. No clinically sign. visual, mobility, or cognitive impairments **Incl.** MoCA; scores ≥26; DGI; scores ≥19**;** Have learned English by the age of 5 yr
Sample Characteristics		29 YA (18-30) 26 OA (65-85) with NH 32 OA (65-85) with ARHL	8 OA with bilateral HL (M_{age}= 73.3) 8 OA with NH (M_{age} = 69.9)
Participants' Characteristics	Hearing	PTA for both ears at .5, 1, 2, and 3 kHz. LSEQ	PTA for each ear at 0.25, 8, 10, and 14 kHz
	Cognitive	MoCA, WAIS-IV and D-KEFS	MoCA
	Balance/ mobility	ABC Scale	TUG < 13.5 sec, DGI
	Physical Activity	N/A	N/A
Single-/Dual-task model		**Mobility task:** perturbation **Cognitive task:** Auditory working memory "n-back" task	**Mobility task:** Standing /Walking (treadmill with VR) **Cognitive task:** Word recognition accuracy
Mobility Task Type		Standing: Sit-to-Stand task Perturb Standing: perturbation platform	Standing: Standing Walking: Walking on treadmill with VR
Dependent Variable		**Balance control/ adjustment** Kinematics: Ankle plantarflexion (AP), Hip extension (HE)	**Balance control/ adjustment** Kinematics: trunk/head angles, step width/ length, stride time, cadence
		Cognitive task performance Accuracy: Auditory working memory	**Cognitive task performance** Accuracy: Word recognition
		Brain Activations N/A	**Brain Activations** N/A
		Dual-tasks costs [single − dual]	**Dual-tasks costs** N/A
Primary outcome of interest		Cognitive accuracy: Group x auditory challenge x attentional load (p=.001); group x auditory challenge (p=.010). AP amplitude, group (p=.002); attentional load (p=0.001) HE amplitude, group x attentional load (p=0.016)	NH vs HL: Word Recognition Accuracy => p=0.024; step width, cadence, velocity, and head/trunk roll => p > 0.05; head pitch, trunk pitch => p < 0.05

Study		**Nieborowska et al. (2019)**	**Wollesen et al. (2018)**
Design		Exploratory, cohort, cross-sectional, prospective	Exploratory, cohort, cross-sectional, prospective
Participants (N)		29	73
Incl./ Excl		**Excl.** N/A **Incl.** 25 dB HL in the better ear; No clinically sign. asymmetry (>15dB interaural difference); Have learned English by the age of 5 yr; no major self-reported. sensory/ sensorimotor/chronic health problems; MoCA >25; DGI ≥19.	**Excl.** N/A **Incl.** Adults seeking audiology services (Past or present client) -Ability to walk (with or without an aid) -Able to independently provide informed consent
Sample Characteristics		17 YA with mean age of 25.53 12 OA with mean age of 66.83	21 with normal hearing 29 with mild HL 23 with moderate/severe HL
Participants' Characteristics	Hearing	PTA for each ear 0.25 to 8.0 kHz	PTA for each ear at 0.5, 1, 2, and 4kHz
	Cognitive	MoCA, LNS, DSC, CWST, DKEFS-TMT	Mini-Cog
	Balance/ mobility	DGI scores ≥19; ABC; TUG	Gait Efficacy Scale, Falls self-efficacy, Quickscreen, SPPB
	Physical Activity	N/A	N/A
Single-/Dual-task model		**Mobility task:** Walking on Treadmill with a VR **Cognitive task:** Auditory Word Recognition Task	**Mobility task:** Walking **Cognitive task:** Visual–Verbal Stroop Task **DT-manual; DT-cognitive; TT: manual and cognitive**
Mobility Task Type		Walking: Treadmill walking	Walking:10-m walk; Walking task (DT/TT)
Dependent Variable		**Balance control/ adjustment** Kinematics: trunk and head angles; Spatiotemporal gait parameters	**Balance control/ adjustment** Kinematics: Walking speed; step length; Cadence
		Cognitive task performance word recognition accuracy	**Cognitive task performance** N/A
		Brain Activations N/A	**Brain Activations** N/A
		Dual-tasks costs listening = single - dual; walking=dual - single	**Dual-tasks costs** ((DT - ST)/ST) × 100)
Primary outcome of interest		Average Head pitch (degrees) Walk:13.8±10.75 (OA), 1.19± 7.77 (YA) Dual: 6.79±9.81 (OA), 1.55±7.18 (YA)	In people with more severe hearing loss: ↓ step length + ↑ cadence: ↓Walking speed

Study		**Carr et al. (2019)**	**Helfer et al. (2020)**
Design		Exploratory, cohort, cross-sectional, prospective	Exploratory, cohort, cross-sectional, prospective
Participants (N)		30	30
Incl./ Excl		**Excl.** N/A **Incl.** ≥60 years; Fluent in English; Normal or corrected-to- normal vision; unimpaired mobility; No known history of stroke and neurological diseases, cognitive impairment, and dementia	**Excl.** N/A **Incl.** Pure-tone thresholds**;** No self-reported otologic, vestibular, motor, or neurological problems that would affect hearing or balance.
Sample Characteristics		14 with Normal cognition (OA) [M = 66.36 yr, SD = 4.80] 16 with SCD group (SCD) [M = 70.63 yr, SD = 6.96]	15 YA with mean age of 21 [range: 19-24] 15 middle age adults with mean age of 54 [Range: 46-63]
Participants' Characteristics	Hearing	PTA, Normal (25 dB) BPTA for .5, 1, 2, 3 kHz, with no asymmetry (interaural difference <15 dB HL)	PTA: (YA) 25 dB from .25 to 8 kHz. (Middle age adults) average high-frequency PTT (2-6 kHz) 60 dB HL in either ear
	Cognitive	MoCA, WAIS-III Digit Span; DSC, Trail Making Test, Rey Auditory Verbal Learning Test	MoCA
	Balance/ mobility	TUG	N/A
	Physical Activity	N/A	N/A
Single-/Dual-task model		**Mobility task:** Sitting & Standing **Cognitive task:** Visual–Verbal Stroop Task	**Mobility task:** Standing / balancing-with-feedback **Cognitive task:** Speech Recognition Task
Mobility Task Type		Standing: standing on firm surface or high-density foam	Standing Postural Instability
Dependent Variable		**Balance control/ adjustment** Kinetics COP path length	**Balance control/ adjustment** Kinetics COP
		Cognitive task performance % correct listening accuracy	**Cognitive task performance** % correct performance (color/ shapes)
		Brain Activations N/A	**Brain Activations** N/A
		Dual-tasks costs N/A	**Dual-tasks costs** Dual-Single
Primary outcome of interest		Significant interaction (group x postural load), F (2, 28) = 6.23, $p < 0.05$.	DT: sig. task (easier/ harder) x group (older/younger) (p=0.028); costs: sig. masker (noise/speech) x group (p=0.026)

APPENDIX B: Correlation between the Average Hearing Thresholds and Timed-Up-and-Go Test Score.

Table B1: The Pearson product-moment correlation coefficient for the bivariate correlations between HT means ($HT_{AllFreq}$, $HT_{LowFreq}$, $HT_{SpeechFreq}$, $HT_{HighFreq}$) and TUG scores.

	Pearson Correlation	**Sig.**	**95% CI**
$HT_{HighFreq}$ - TUG	0.152	<.001	[0.134, 0.170]
$HT_{SpeechFreq}$ - TUG	0.162	<.001	[0.144, 0.180]
$HT_{LowFreq}$ - TUG	0.169	<.001	[0.151, 0.187]
$HT_{AllFreq}$ - TUG	0.171	<.001	[0.154, 0.189]

APPENDIX C: Correlation Matrices Output

Table C1: Correlation coefficients to assess collinearity among variables.

	Correlation Coefficient	***p*-value**	**95% CI**	
			Lower	**Upper**
Age - Sex	-0.017	0.11	-0.038	0.004
HT - Age	0.430	<.001	0.413	0.446
HT - Sex^{+}	-0.224	<.001	-0.244	-0.204
HT - VA	0.102	<.001	0.081	0.122
HT - MAT	-0.111	<.001	-0.131	-0.091
HT - LSI	-0.069	<.001	-0.090	-0.049
HT - FI$_{46}$	0.161	<.001	0.141	0.181
VA - Sex	0.049	<.001	0.028	0.070
VA - Age	0.216	<.001	0.197	0.236
VA - MAT	-0.080	<.001	-0.101	-0.060
VA - LSI	-0.056	<.001	-0.077	-0.036
VA - FI$_{46}$	0.109	<.001	0.089	0.130
MAT - Sex	-0.096	<.001	-0.117	-0.075
MAT - Age	-0.185	<.001	-0.204	-0.165
MAT - LSI	0.123	<.001	0.102	0.143
MAT - FI$_{46}$	-0.174	<.001	-0.194	-0.154
LSI - Sex	-0.169	<.001	-0.190	-0.149
LSI - Age	-0.156	<.001	-0.176	-0.136
LSI - FI$_{46}$	-0.217	<.001	-0.236	-0.197
FI$_{46}$ - Sex	0.1	<.001	0.079	0.121
FI$_{46}$ - Age	0.292	<.001	0.273	0.311

APPENDIX D: Descriptive Statistics for the Explanatory Variables

Table D1: Participants' demographics and characteristics.

		Variables					
		Age (years)			Weight (kg)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	73.1 (±5.6)	73.1 (±5.7)	73.1 (±5.7)	84.5 (±14.4)	71.1 (±14.8)	77.8 (±16.1)
	Weighted	72.7 (±5.6)	73 (±5.7)	72.9 (±5.6)	84.9 (±14.7)	70.7 (±14.4)	77.1 (±16.2)
Median	Raw	73	72	73	83.1	69.1	76.7
	Weighted	72	72	72	83.2	68.8	75.7
Mode	Raw	65	65	65	82.6	68	67
	Weighted	65	66	65	87.5	60.1	83
Min	Raw	65	65	65	38	34.9	34.9
	Weighted	65	65	65	38	34.9	34.9
Max	Raw	86	86	86	168.5	175.2	175.2
	Weighted	86	86	86	168.5	175.2	175.2
Range	Raw	21	21	21	130.5	140.3	140.3
	Weighted	21	21	21	130.5	140.3	140.3
Skewness (SE_S)	Raw	0.274 (0.031)	0.293 (0.031)	0.284 (0.022)	0.780 (0.031)	0.972 (0.031)	0.634 (0.022)
	Weighted	0.399 (0.003)	0.303 (0.003)	0.346 (0.002)	0.836 (0.003)	0.953 (0.003)	0.695 (0.002)
Kurtosis (SE_K)	Raw	-1.054 (0.062)	-1.063 (0.062)	-1.059 (0.044)	1.447 (0.062)	1.920 (0.062)	0.935 (0.044)
	Weighted	-0.946 (0.007)	-1.04 (0.006)	-1.002 (0.005)	1.368 (0.007)	1.847 (0.006)	0.963 (0.005)
Absolute N	Raw	6,340	6,306	12,646	6,317	6,273	12,646
	Weighted	518,340	623,795	1,142,135	518,340	623,795	1,142,135
Missing n (%)	Raw	0 (0.0)	0 (0.0)	0 (0.0)	23 (0.4)	33 (0.5)	56 (0.4)
	Weighted	0 (0.0)	0 (0.0)	0 (0.0)	2012 (0.4)	4233 (0.7)	6246 (0.5)

		Variables					
		Height (m)			Body Mass Index		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	1.74 (±0.07)	1.60 (±0.06)	1.67 (±0.1)	27.9 (±4.3)	27.9 (±5.7)	27.9 (±5.0)
	Weighted	1.73 (±0.07)	1.60 (±0.06)	1.65 (±0.1)	28.3 (±4.4)	27.9 (±5.5)	28.1 (±5.0)
Median	Raw	1.74	1.60	1.66	27.4	27	27.3
	Weighted	1.73	1.60	1.64	27.7	27.2	27.5
Mode	Raw	1.71	1.6	1.6	21.9	21	21
	Weighted	1.71	1.52	1.6	27.2	32	32
Min	Raw	1.25	1.17	1.17	13.9	12.9	12.9
	Weighted	1.25	1.17	1.17	13.9	12.9	12.9
Max	Raw	2.01	1.87	2.01	53.3	69.6	69.6
	Weighted	2.01	1.87	2.01	53.3	69.6	69.6
Range	Raw	0.76	0.70	0.84	39.4	56.7	56.7
	Weighted	0.76	0.70	0.84	39.4	56.7	56.7
Skewness (SE_S)	Raw	-0.0366 (0.031)	-0.0004 (0.031)	0.071 (0.022)	0.907 (0.031)	1.067 (0.031)	1.037 (0.022)
	Weighted	-0.011 (0.003)	0.018 (0.003)	0.158 (0.002)	0.934 (0.003)	0.896 (0.003)	0.902 (0.002)
Kurtosis (SE_K)	Raw	0.4764 (0.062)	0.5411 (0.062)	-0.468 (0.044)	1.957 (0.062)	2.322 (0.062)	2.58 (0.044)
	Weighted	0.401 (0.007)	0.238 (0.006)	-0.434 (0.005)	1.815 (0.007)	1.661 (0.006)	1.864 (0.005)
Absolute N	Raw	6,318	6,278	12,596	6,314	6,271	12,585
	Weighted	516,262	620,588	1,136,850	516,102	6,199,227	113,5330
Missing n (%)	Raw	22 (0.3)	28 (0.4)	50 (0.4)	26 (0.4)	35 (0.6)	61 (0.5)
	Weighted	2,078 (0.4)	3,207 (0.5)	5,285 (0.5)	2,238 (0.4)	4,568 (0.7)	6,805 (0.6)

		Variables					
		Frailty Index (FI_{52})			Hand Grip Strength (Kg)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	0.11 (±0.06)	0.12 (±0.06)	0.12 (±0.06)	39.22 (±8.59)	23.51 (±5.25)	31.62 (±10.63)
	Weighted	0.11 (±0.06)	0.12 (±0.06)	0.12 (±0.06)	39.11 (±8.28)	23.30 (±5.09)	30.82 (±10.42)
Median	Raw	0.10	0.11	0.11	39.17	23.44	29.85
	Weighted	0.10	0.12	0.11	39.08	23.39	28.70
Mode	Raw	0.07	0.06	0.08	35.38	23.59	23.59
	Weighted	0.08	0.11	0.08	38.55	26.06	26.06
Min	Raw	0.00	0.00	0.00	9.21	0.20	0.20
	Weighted	0.00	0.00	0.00	9.21	0.20	0.20
Max	Raw	0.41	0.51	0.51	75.87	48.36	75.87
	Weighted	0.41	0.51	0.51	75.87	48.36	75.87
Range	Raw	0.41	0.51	0.51	66.66	48.16	75.67
	Weighted	0.41	0.51	0.51	66.66	48.16	75.67
Skewness (SE_S)	Raw	0.8 (0.03)	0.9 (0.03)	0.9 (0.02)	0.092 (0.032)	0.089 (0.033)	0.457 (0.023)
	Weighted	0.885 (0.003)	0.869 (0.003)	0.899 (0.002)	0.066 (0.004)	0.053 (0.003)	0.508 (0.002)
Kurtosis (SE_K)	Raw	0.9 (0.06)	1.3 (0.06)	1.2 (0.04)	0.239 (0.064)	0.416 (0.066)	-0.390 (0.046)
	Weighted	1.039 (0.007)	1.265 (0.006)	1.267 (0.005)	0.259 (0.007)	0.435 (0.007)	-0.372 (0.005)
Absolute N	Raw	6,315	6,275	12,590	5,890	5,526	11,416
	Weighted	516,780	621,680	1,138,460	477,264	525,993	1,003,257
Missing n (%)	Raw	25 (0.4)	31 (0.5)	56 (0.4)	450 (7.1)	780 (12.4)	1,230 (9.7)
	Weighted	1,560 (0.3)	2,115 (0.3)	3,675 (0.3)	41,076 (7.9)	97,802 (15.7)	138,878 (12.2)

		Variables					
		Chair Rise Score (s)			Single Leg Standing Score (s)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	2.81 (±0.79)	2.93 (±0.91)	2.87 (±0.85)	27.74 (±22.99)	24.34 (±22.07)	26.07 (±22.61)
	Weighted	2.81 (±0.77)	2.99 (±1.06)	2.91 (±0.94)	26.73 (±22.81)	22.41 (±21.51)	24.40 (±22.22)
Median	Raw	2.72	2.81	2.76	19.18	14.81	16.81
	Weighted	2.73	2.86	2.79	18.06	12.34	14.72
Mode	Raw	2.65	2.50	2.50	60.00	60.00	60.00
	Weighted	2.90	2.76	2.99	60.00	60.00	60.00
Min	Raw	0.73	0.71	0.71	0.05	0.04	0.04
	Weighted	0.73	0.71	0.71	0.05	0.04	0.04
Max	Raw	12.31	25.80	25.80	60.00	60.00	60.00
	Weighted	12.31	25.80	25.80	60.00	60.00	60.00
Range	Raw	11.58	25.09	25.09	59.95	59.96	59.96
	Weighted	11.58	25.09	25.09	59.95	59.96	59.96
Skewness (SE_S)	Raw	1.885 (0.032)	4.201 (0.032)	3.32 (0.02)	0.39 (0.03)	0.66 (0.03)	0.52 (0.02)
	Weighted	1.390 (0.004)	6.561 (0.003)	5.523 (0.002)	0.459 (0.004)	0.803 (0.003)	0.638 (0.002)
Kurtosis (SE_K)	Raw	12.651 (0.063)	74.193 (0.064)	53.2 (0.04)	-1.5 (0.06)	-1.19 (0.06)	-1.4 (0.05)
	Weighted	7.625 (0.007)	118.8 (0.006)	107.38 (0.005)	-1.451 (0.007)	-0.936 (0.007)	-1.219 (0.005)
Absolute N	Raw	5,951	5,839	12,646	5,816	5,598	11,414
	Weighted	481,295	571,092	1,052,388	469,244	549,985	1,019,229
Missing n (%)	Raw	389 (6.1)	467 (7.4)	856 (6.8)	524 (8.3)	708 (11.2)	1,232 (9.7)
	Weighted	37,045 (7.1)	52,703 (8.4)	89,747 (7.9)	49,096 (9.5)	73,810 (11.8)	122,906 (10.8)

		Variables					
		Timed 4-meter walk test (s)			Gait Velocity ($m.s^{-1}$)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	4.50 (±1.16)	4.73 (±1.26)	4.62 (±1.21)	0.93 (±0.20)	0.89 (±0.20)	0.91 (±0.19)
	Weighted	4.57 (± 1.26)	4.82 (± 1.32)	4.71 (±1.30)	0.92 (±0.19)	0.88 (±0.20)	0.90 (±0.20)
Median	Raw	4.31	4.50	4.40	0.93	0.89	0.91
	Weighted	4.38	4.54	4.47	0.91	0.88	0.89
Mode	Raw	3.75	4.25	4.25	1.07	0.94	0.94
	Weighted	4.75	4.00	4.25	0.84	1.00	0.94
Min	Raw	1.72	1.78	1.72	0.20	0.20	0.20
	Weighted	1.72	1.78	1.72	0.20	0.20	0.20
Max	Raw	18.57	19.56	19.56	2.33	2.25	2.33
	Weighted	18.57	19.56	19.56	2.33	2.25	2.33
Range	Raw	16.85	17.78	17.84	2.12	2.04	2.12
	Weighted	16.85	17.78	17.84	2.12	2.04	2.12
Skewness (SE_S)	Raw	2.899 (0.031)	2.189 (0.031)	2.496 (0.022)	0.355 (0.031)	0.292 (0.031)	0.316 (0.022)
	Weighted	3.820 (0.003)	2.266 (0.003)	2.893 (0.002)	0.299 (0.003)	0.275 (0.003)	0.275 (0.002)
Kurtosis (SE_K)	Raw	20.011 (0.062)	10.375 (0.062)	14.228 (0.044)	1.572 (0.062)	1.192 (0.062)	1.361 (0.044)
	Weighted	27.95 (0.007)	10.061 (0.006)	16.866 (0.005)	1.823 (0.007)	1.459 (0.006)	1.582 (0.005)
Absolute N	Raw	6,236	6,197	12,433	6,236	6,197	12,433
	Weighted	505,112	606,712	1,111,824	505,112	606,712	1,111,824
Missing n (%)	Raw	104 (1.6)	109 (1.7)	213 (1.7)	104 (1.6)	109 (1.7)	213 (1.7)
	Weighted	13,228 (2.6)	17,083 (2.7)	30,311 (2.7)	13,228 (2.6)	17,083 (2.7)	30,311 (2.7)

		Variables					
		Life Space Index			Visual Acuity (logMAR)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	83.7 (±17.6)	77.3 (±18.6)	80.5 (±18.4)	0.09 (±0.16)	0.11 (±0.15)	0.10 (±0.16)
	Weighted	85.2 (±17.6)	77.9 (±18.4)	81.2 (±18.4)	0.10 (±0.16)	0.11 (±0.15)	0.11 (±0.16)
Median	Raw	84	80	82	0.06	0.10	0.08
	Weighted	86	80	82	0.06	0.10	0.10
Mode	Raw	100	100	100	0.02	0.12	0.02
	Weighted	100	92	100	0.02	0.12	0.12
Min	Raw	0.0	0.0	0.0	-0.38	-0.38	-0.38
	Weighted	0.0	0.0	0.0	-0.38	-0.38	-0.38
Max	Raw	120	120	120	1.00	1.00	1.00
	Weighted	120	120	120	1.00	0.98	1.00
Range	Raw	120	120	120	1.38	1.34	1.38
	Weighted	120	120	120	1.38	1.34	1.38
Skewness (SE_S)	Raw	-0.45 (0.03)	-0.31 (0.03)	-0.39 (0.02)	0.948 (0.031)	1.172 (0.031)	1.043 (0.022)
	Weighted	-0.482 (0.003)	-0.365 (0.003)	-0.415 (0.002)	1.050 (0.003)	0.995 (0.003)	1.011 (0.002)
Kurtosis (SE_K)	Raw	0.32 (0.06)	0.13 (0.06)	0.18 (0.04)	1.828 (0.062)	2.854 (0.062)	2.301 (0.044)
	Weighted	0.306 (0.007)	0.118 (0.006)	0.159 (0.005)	2.405 (0.007)	1.890 (0.006)	2.158 (0.005)
Absolute N	Raw	6,328	6,287	12,615	6,229	6,188	12,417
	Weighted	516,820	622,568	1,139,388	504,922	603,759	1,108,680
Missing, n (%)	Raw	12 (0.2)	19 (0.3)	31 (0.2)	111 (1.8)	118 (1.9)	229 (1.8)
	Weighted	1,520 (0.3)	1,227 (0.2)	2,747 (0.2)	13,418 (2.6)	20,036 (3.2)	33,455 (2.9)

		Variables					
		Mental Alternation Test			Timed Up and Go (s)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	25.0 (±8.8)	23.4 (±8.4)	24.2 (±8.6)	10.29 (±2.83)	10.49 (±3.01)	10.39 (±2.92)
	Weighted	23.8 (±8.9)	22.1 (±8.4)	22.9 (±8.7)	10.58 (±3.99)	10.83 (±3.55)	10.72 (±3.76)
Median	Raw	25	23	24	9.87	9.94	9.91
	Weighted	24	22	23	10.03	10.22	10.13
Mode	Raw	29	23	22	9.25	8.97	10.25
	Weighted	24	22	22	9.78	9.97	10.25
Min	Raw	0.0	0.0	0.0	2.97	2.79	2.79
	Weighted	0.0	0.0	0.0	2.97	2.79	2.79
Max	Raw	51	51	51	68.00	104.06	104.06
	Weighted	51	51	51	68.00	104.06	104.06
Range	Raw	51	51	51	65.03	101.27	101.27
	Weighted	51	51	51	65.03	101.27	101.27
Skewness (SE$_{S}$)	Raw	-0.26 (0.03)	-0.41 (0.03)	-0.31 (0.02)	5.164 (0.031)	6.825 (0.031)	6.074 (0.022)
	Weighted	-0.269 (0.004)	-0.345 (0.003)	-0.286 (0.002)	8.999 (0.003)	10.447 (0.003)	9.687 (0.002)
Kurtosis (SE$_{K}$)	Raw	0.27 (0.06)	0.49 (0.06)	0.39 (0.04)	69.814 (0.062)	160.740 (0.062)	121.188 (0.044)
	Weighted	0.105 (0.007)	0.28 (0.006)	0.20 (0.005)	119.744 (0.007)	247.346 (0.006)	176.531 (0.005)
Absolute N	Raw	5,921	5,925	11,846	6,213	6,171	12,384
	Weighted	478,834	584,974	1,063,808	502,560	605,317	1,107,877
Missing n (%)	Raw	419 (6.6)	381 (6)	800 (6.3)	127 (2.0)	135 (2.1)	262 (2.1)
	Weighted	39,506 (7.6)	623,795 (6.2)	78,327 (6.9)	15,780 (3)	18,478 (3)	34,258 (3)

		Variables					
		$HT_{Left, 1K}$ (dB)			$HT_{Left, 2K}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	19.53 (±15.6)	19.76 (±14.5)	19.64 (±15.1)	28.87 (±19.7)	25.04 (±16.7)	26.96 (±18.4)
	Weighted	19.87 (±15.6)	20.6 (±14.7)	20.25 (±15.1)	29.33 (±20.1)	25.3 (±16.3)	27.15 (±18.2)
Median	Raw	15	15	15	25	20	25
	Weighted	15	15	15	25	20	25
Mode	Raw	10	10	10	20	15	20
	Weighted	10	10	10	20	20	20
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	99	99	99	105	105	105
	Weighted	99	99	99	105	105	105
Range	Raw	99	99	99	105	105	105
	Weighted	99	99	99	105	105	105
Skewness (SE_S)	Raw	1.55 (0.03)	1.588 (0.03)	1.566 (0.022)	0.823 (0.03)	1.008 (0.03)	0.937 (0.022)
	Weighted	1.50 (0.003)	1.64 (0.003)	1.565 (0.002)	0.82 (0.003)	1.13 (0.003)	1.01 (0.002)
Kurtosis (SE_K)	Raw	2.99 (0.063)	3.781 (0.06)	3.354 (0.044)	0.396 (0.06)	1.368 (0.06)	0.859 (0.044)
	Weighted	2.65 (0.007)	4.11 (0.006)	3.379 (0.005)	0.35 (0.007)	2.08 (0.006)	1.15 (0.005)
Absolute N	Raw	6,112	6,072	12,184	6,110	6,063	12,173
	Weighted	497,943	597,312	1,095,255	497,875	596,442	1,094,317
Missing n	Raw	228	234	462	230	243	473
	Weighted	20,397	26,483	46,880	20,465	27,353	47,818

		Variables					
		$HT_{Left, 3K}$ (dB)			$HT_{Left, 4K}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	41.58 (±21.1)	30.44 (±17.9)	36.03 (±20.3)	49.79 (±20.8)	36.32 (±19.3)	43.08 (±21.2)
	Weighted	42.33 (±21.3)	31.3 (±17.5)	36.3 (±20.1)	50.00 (±20.8)	37.32 (±19.1)	43.09 (±20.8)
Median	Raw	40	30	35	50	35	40
	Weighted	40	30	35	50	35	45
Mode	Raw	55	20	20	55	20	45
	Weighted	55	20	25	55	20	45
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	0.31 (0.03)	0.79 (0.03)	0.566 (0.022)	0.091 (0.031)	0.561 (0.031)	0.32 (0.022)
	Weighted	0.25 (0.003)	0.74 (0.003)	0.559 (0.002)	0.034 (0.003)	0.523 (0.003)	0.31 (0.002)
Kurtosis (SE_K)	Raw	-0.32 (0.063)	0.812 (0.063)	0.002 (0.044)	-0.256 (0.063)	0.187 (0.063)	-0.277 (0.044)
	Weighted	-0.34 (0.007)	0.68 (0.006)	0.019 (0.005)	-0.18 (0.007)	0.04 (0.006)	-0.275 (0.005)
Absolute N	Raw	6,107	6,060	12,167	6,102	6,054	12,156
	Weighted	497,720	595,230	1,092,950	496,224	594,508	1,090,733
Missing n	Raw	233	246	479	238	252	490
	Weighted	20,620	28,565	49,185	22,116	29,287	51,402

		Variables					
		$HT_{\text{Left, 0.5K}}$ (dB)			$HT_{\text{Left, 6K}}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	24.03 (±14.3)	25.79 (±13.9)	24.91 (±14.12)	61.72 (±22.2)	50.38 (±21.7)	56.07 (±22.7)
	Weighted	24.3 (±13.7)	26.82 (±14.2)	25.67 (±14.06)	62.13 (±22.2)	51.13 (±21.2)	56.12 (±22.4)
Median	Raw	20	25	20	65	50	55
	Weighted	20	25	25	65	50	55
Mode	Raw	20	20	20	70	60	60
	Weighted	20	20	20	65	50	65
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	1.549 (0.031)	1.546 (0.031)	1.533 (0.022)	-0.085 (0.031)	0.214 (0.031)	0.071 (0.022)
	Weighted	1.482 (0.003)	1.61 (0.003)	1.55 (0.002)	-0.119 (0.003)	0.20 (0.003)	0.078 (0.002)
Kurtosis (SE_K)	Raw	3.943 (0.063)	4.127 (0.063)	3.985 (0.044)	-0.508 (0.063)	-0.486 (0.063)	-0.577 (0.044)
	Weighted	3.99 (0.007)	4.48 (0.006)	4.27 (0.005)	-0.47 (0.007)	-0.50 (0.006)	-0.571 (0.005)
Absolute N	Raw	6,126	6,093	12,219	6,089	6,048	12,137
	Weighted	498,932	599,660	1,098,592	494,262	594,347	1,088,609
Missing n	Raw	214	213	427	251	258	509
	Weighted	19,408	24,135	43,543	24,078	29,448	53,526

		Variables					
		$\mathrm{HT}_{\mathrm{Left,\ 8K}}$ (dB)			$\mathrm{HT}_{\mathrm{Right,\ 1K}}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	67.23 (±22.3)	58.27 (±23.0)	62.76 (±22.9)	19.41 (±14.6)	20.49 (±14.1)	19.95 (±14.4)
	Weighted	66.45 (22.3)	58.68 (±22.8)	62.21 (±22.9)	19.94 (±14.6)	20.96 (±13.6)	20.49 (±14.1)
Median	Raw	70	60	65	15	15	15
	Weighted	70	60	65	15	20	20
Mode	Raw	70	65	65	10	15	10
	Weighted	70	70	70	10	15	10
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SES)	Raw	-0.411 (0.031)	-0.169 (0.032)	-0.292 (0.022)	1.481 (0.032)	1.477 (0.032)	-0.501 (0.022)
	Weighted	-0.371 (0.003)	-0.16 (0.003)	-0.256 (0.002)	1.4 (0.003)	1.32 (0.003)	-0.523 (0.002)
Kurtosis (SEK)	Raw	-0.297 (0.063)	-0.603 (0.063)	-0.501 (0.045)	3.14 (0.063)	3.535 (0.063)	3.307 (0.045)
	Weighted	-0.327 (0.007)	-0.613 (0.006)	-0.523 (0.005)	2.54 (0.007)	2.92 (0.006)	2.715 (0.005)
Absolute N	Raw	6,063	6,034	12,097	6,013	5,963	11,976
	Weighted	494,019	593,487	1,087,506	491,355	586,086	1,077,442
Missing n	Raw	277	272	549	327	343	670
	Weighted	24,321	30,308	54,629	26,985	37,709	64,693

		Variables					
		$HT_{Right, 2K}$ (dB)			$HT_{Right, 3K}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	26.95 (±18.8)	24.82 (±16.2)	25.89 (±17.6)	38.57 (±21.0)	29.21 (±17.8)	33.91 (±20.0)
	Weighted	27.72 (±19.1)	25.21 (±15.8)	26.35 (±17.4)	39.59 (±21.2)	29.68 (±17.3)	34.2 (±19.8)
Median	Raw	25	20	20	35	25	30
	Weighted	25	20	25	40	25	30
Mode	Raw	10	20	20	20	20	20
	Weighted	10	20	20	20	20	20
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	0.893 (0.032)	0.965 (0.032)	0.949 (0.022)	0.376 (0.032)	0.832 (0.032)	0.618 (0.022)
	Weighted	0.855 (0.003)	0.93 (0.003)	0.929 (0.002)	0.321 (0.003)	0.77 (0.003)	0.604 (0.002)
Kurtosis (SE_K)	Raw	0.557 (0.063)	1.187 (0.063)	0.893 (0.045)	-0.378 (0.063)	0.786 (0.064)	0.011 (0.045)
	Weighted	4.50 (0.007)	1.05 (0.006)	0.768 (0.005)	-0.46 (0.007)	0.57 (0.006)	-0.039 (0.005)
Absolute N	Raw	6,007	5,954	11,961	5,997	5,945	11,942
	Weighted	491,006	585,588	1,076,594	490,223	585,227	1,075,450
Missing n	Raw	333	352	685	343	361	704
	Weighted	27,334	38,207	65,541	28,117	38,568	66,685

		Variables					
		$HT_{\text{Right, 4K}}$ (dB)			$HT_{\text{Right, 0.5K}}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	46.76 (±21.4)	34.46 (±19.2)	40.63 (±21.2)	22.33 (±13.6)	24.82 (±13.6)	23.57 (±13.7)
	Weighted	47.62 (±21.3)	35.11 (±18.8)	40.81 (±20.9)	22.39 (±12.7)	24.73 (±12.6)	23.66 (±12.7)
Median	Raw	45	30	40	20	20	20
	Weighted	50	35	40	20	25	20
Mode	Raw	50	25	25	20	20	20
	Weighted	50	30	35	20	20	20
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	0.176 (0.032)	0.598 (0.032)	0.394 (0.022)	1.772 (0.031)	1.77 (0.032)	1.748 (0.022)
	Weighted	0.187 (0.004)	0.519 (0.003)	0.399 (0.002)	1.512 (0.003)	1.516 (0.003)	1.492 (0.002)
Kurtosis (SE_K)	Raw	-0.411 (0.063)	0.15 (0.064)	-0.301 (0.045)	5.844 (0.063)	5.974 (0.063)	5.804 (0.045)
	Weighted	-0.421 (0.007)	-0.08 (0.006)	-0.309 (0.005)	4.543 (0.007)	4.97 (0.006)	4.683 (0.005)
Absolute N	Raw	5,983	5,938	11,921	6,069	6,025	12,094
	Weighted	489,238	584,739	1,073,977	494,651	591,992	1,086,643
Missing n	Raw	357	368	725	271	281	552
	Weighted	29,102	39,056	68,158	23,689	31,803	55,492

		Variables					
		$HT_{Right, 6K}$ (dB)			$HT_{Right, 8K}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	59.32 (±22.7)	48.58 (±21.7)	53.97 (±22.9)	66.65 (±23.1)	58.05 (±23.4)	62.36 (±23.6)
	Weighted	59.97 (±22.7)	49.08 (±21.7)	54.04 (±22.8)	66.68 (±22.9)	57.75 (±22.8)	61.82 (±23.3)
Median	Raw	60	50	55	70	60	65
	Weighted	60	50	55	70	60	65
Mode	Raw	65	50	60	70	65	65
	Weighted	65	30	65	75	65	65
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	-0.034 (0.032)	0.283 (0.032)	0.134 (0.022)	-0.405 (0.032)	-0.098 (0.032)	-0.244 (0.022)
	Weighted	-0.03 (0.004)	0.25 (0.003)	0.136 (0.002)	-0.377 (0.004)	-0.107 (0.003)	-0.215 (0.002)
Kurtosis (SE_K)	Raw	-0.618 (0.063)	-0.463 (0.064)	-0.621 (0.045)	-0.455 (0.064)	-0.678 (0.064)	-0.637 (0.045)
	Weighted	-0.643 (0.007)	-0.51 (0.006)	-0.626 (0.005)	-0.50 (0.007)	-0.668 (0.006)	-0.652 (0.005)
Absolute N	Raw	5,962	5,914	11,876	5,941	5,904	11,845
	Weighted	488,548	583,461	1,072,009	486,086	582,264	1,068,351
Missing n	Raw	378	392	770	399	402	801
	Weighted	29,792	40,334	70,126	32,254	41,531	73,784

		Variables					
		HT$_{HighFreq}$ (dB)			HT$_{SpeechFreq}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	54.06 (±18.4)	43.28 (±17.4)	48.69 (±18.7)	31.93 (±14.3)	27.28 (±13.2)	29.61 (±13.9)
	Weighted	54.42 (±18.4)	43.75 (±16.9)	48.61 (±18.2)	32.36 (±14.2)	27.89 (±12.9)	29.92 (±13.7)
Median	Raw	55	42.5	48.75	30.5	25	27.5
	Weighted	55	42.5	48.75	31	25.5	27.5
Mode	Raw	50.00	37.5	50	20	20	20
	Weighted	58.13	30.63	30.63	23.5	20	20
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE$_S$)	Raw	-0.029 (0.031)	0.314 (0.031)	0.156 (0.022)	0.745 (0.031)	1.051 (0.031)	0.885 (0.022)
	Weighted	-0.007 (0.003)	0.251 (0.003)	0.173 (0.002)	0.7 (0.003)	1.17 (0.003)	0.935 (0.002)
Kurtosis (SE$_K$)	Raw	-0.505 (0.063)	-0.355 (0.063)	-0.538 (0.044)	0.888 (0.063)	1.759 (0.063)	1.18 (0.044)
	Weighted	-0.48 (0.007)	-0.509 (0.006)	-0.524 (0.005)	0.591 (0.007)	2.863 (0.006)	1.511 (0.005)
Absolute N	Raw	6,118	6,067	12,185	6,134	6,101	12,235
	Weighted	498,006	595,463	1,093,469	499,419	600,038	1,099,457
Missing n	Raw	222	239	461	206	205	411
	Weighted	20,334	28,332	48,666	18,921	23,757	42,678

		Variables					
		$HT_{LowFreq}$ (dB)			$HT_{AllFreq}$ (dB)		
		Male	Female	Total	Male	Female	Total
Mean (± SD)	Raw	23.71 (±13.1)	23.62 (±12.2)	23.67 (±12.7)	40.95 (±14.9)	34.80 (±14.2)	37.88 (±14.9)
	Weighted	24.03 (±12.9)	24.13 (±12.2)	24.08 (±12.5)	41.27 (±14.8)	35.34 (±13.9)	38.03 (±14.7)
Median	Raw	20.83	20.83	20.8333	40.36	33.21	36.7857
	Weighted	21.67	21.67	21.6667	41.07	34.29	37.1429
Mode	Raw	12.50	15	15	36.07	23.21	36.07
	Weighted	17.5	15	15	45	35	35
Min	Raw	0	0	0	0	0	0
	Weighted	0	0	0	0	0	0
Max	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Range	Raw	105	105	105	105	105	105
	Weighted	105	105	105	105	105	105
Skewness (SE_S)	Raw	1.28 (0.031)	1.351 (0.031)	1.315 (0.022)	0.351 (0.031)	0.655 (0.031)	0.491 (0.022)
	Weighted	1.153 (0.003)	1.568 (0.003)	1.363 (0.002)	0.335 (0.003)	0.709 (0.003)	0.529 (0.002)
Kurtosis (SE_K)	Raw	2.722 (0.063)	3.198 (0.063)	2.954 (0.044)	0.02 (0.063)	0.49 (0.063)	0.127 (0.044)
	Weighted	1.904 (0.007)	5.216 (0.006)	3.547 (0.005)	-0.069 (0.007)	0.973 (0.006)	0.307 (0.005)
Absolute N	Raw	6,134	6,101	12,235	6,134	6,101	12,235
	Weighted	499,419	600038	1,099,457	499,419	600,038	1,099,457
Missing n	Raw	206	205	411	206	205	411
	Weighted	18,921	23757	42,678	1,8921	23,757	42,678

Table D2: Sex.

		Frequency (n)		Percentage (%)	
		Raw	Weighted	Raw	Weighted
Sex	**Male**	6,340	518,340	50.1	45.4
	Female	6,306	623,795	49.9	54.6
Absolute N		12,646	1,142,135	12,646	1,142,135
Missing		0	0	0	0

Table D3: Most frequent countries of birth.

Country		Males		Females		Total	
		N	%	N	%	N	%
Canada	Raw	4,786	75.5	5,025	79.7	9,811	77.6
	Weighted	388,881	75	486,045	77.9	874,926	76.6
United Kingdom	Raw	556	8.8	449	7.1	1,005	7.9
	Weighted	37,453	7.2	39,374	6.3	76,827	6.7
United States	Raw	181	2.9	169	2.7	350	2.8
	Weighted	8,962	1.7	10,611	1.7	19,574	1.7
Germany	Raw	83	1.3	90	1.4	173	1.4
	Weighted	9,931	1.9	9,477	1.5	19,408	1.7
Netherlands/Holland	Raw	102	1.6	73	1.2	175	1.4
	Weighted	8,523	1.6	9,835	1.6	18,359	1.6
France	Raw	43	0.7	41	0.7	84	0.7
	Weighted	5,069	1	6,245	1	11,314	1
India	Raw	57	0.9	19	0.3	76	0.6
	Weighted	2,764	0.5	1,332	0.2	4,096	0.4
Scotland	Raw	17	0.3	27	0.4	44	0.3
	Weighted	1,199	0.2	2,085	0.3	3,284	0.3
Italy	Raw	48	0.8	31	0.5	79	0.6
	Weighted	6,659	1.3	10,514	1.7	17,173	1.5

Table D4: Measures of frequency and percentage for marital/partner status.

Variable Marital/partner Status	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
Single, never married or never lived with a partner	302 (4.8)	25,044 (4.8)	437 (6.9)	33,918 (5.4)	739 (5.8)	58,962 (5.2)
Married/Living with a partner in a common-law relationship	4,856 (76.6)	410,395 (79.2)	3,014 (47.8)	335,838 (53.8)	7,870 (62.2)	746,232 (65.3)
Widowed	600 (9.5)	41,558 (8.0)	1,710 (27.1)	150,952 (24.2)	2,310 (18.3)	192,510 (16.9)
Divorced	459 (7.2)	33,058 (6.4)	1,023 (16.2)	89,464 (14.3)	1,482 (11.7)	122,522 (10.7)
Separated	119 (1.9)	8,085 (1.6)	116 (1.8)	13,250 (2.1)	235 (1.9)	21,335 (1.9)
Refused	0 (0.0)	0 (0.0)	1 (0.0)	20 (0.0)	1 (0.0)	20 (0.0)
Absolute N	6,336	518,140	6,301	623,442	12,637	1,141,582
Missing	4 (0.1)	200 (0.0)	5 (0.1)	353 (0.1)	9 (0.1)	553 (0.0)

APPENDIX E: Classifications

Table E1: Participants’ demographics and characteristics, classified.

Variable		**Male**		**Female**		**Total**	
		N	%	N	%	N	%
Body Mass Index							
BMI < 18.5	Raw	22	0.3	84	1.3	106	0.8
	Weighted	1,011	0.2	9,309	1.5	10,320	0.9
18.5≤BMI < 25	Raw	1,536	24.2	1,998	31.7	3,534	27.9
	Weighted	117,707	22.7	184,482	29.6	302,190	26.5
25≤ BMI < 30	Raw	3,063	48.3	2,334	37	5,397	42.7
	Weighted	245,189	47.3	231,170	37.1	476,358	41.7
BMI ≥30	Raw	1,693	26.7	1,855	29.4	3,548	28.1
	Weighted	152,195	29.4	194,266	31.1	346,462	30.3
Frailty Index (FI_{52})							
FI ≤ 0.1	Raw	3,503	55.3	2,932	46.5	6,435	50.9
	Weighted	285,901	55.2	281,568	45.1	567,469	49.7
0.11 ≤ FI ≤ 0.2	Raw	2,410	38	2,723	43.2	5,133	40.6
	Weighted	197,998	38.2	275,539	44.2	473,537	41.5
0.21 ≤ FI ≤ 0.3	Raw	369	5.8	559	8.9	928	7.3
	Weighted	30,262	5.8	57,604	9.2	87,866	7.7
FI ≥0.31	Raw	27	0.4	57	0.9	84	0.7
	Weighted	2,311	0.4	6,861	1.1	9,172	0.8
Visual Acuity (logMAR)							
VA <0.3	Raw	5,495	86.7	5,472	86.8	10,967	86.7
	Weighted	445,914	86	533,612	85.5	979,525	85.8
0.3≤ VA < 1	Raw	754	11.9	748	11.9	1,502	11.9
	Weighted	61,195	11.8	76,248	12.2	137,442	12
VA ≥ 1	Raw	3	0	0	0	3	0
	Weighted	146	0	0	0	146	0

Table E2: Hearing device use.

Variable Hearing Device Use	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
Hearing Aid	808 (77.9)	65,245 (72.4)	460 (77.7)	38,130 (72.4)	1,268 (77.8)	103,375 (72.4)
Computer to communicate (e.g., e-mail or chat services)	8 (0.8)	820 (0.9)	5 (0.8)	737 (1.4)	13 (0.8)	1,558 (1.1)
Volume control telephone	67 (6.5)	6,846 (7.6)	41 (6.9)	3,414 (6.5)	108 (6.6)	10,260 (7.2)
TTY or TTD	2 (0.2)	99 (0.1)	3 (0.5)	195 (0.4)	5 (0.3)	294 (0.2)
Message relay service	3 (0.3)	312 (0.3)	0 (0.0)	0 (0.0)	3 (0.2)	312 (0.2)
Other phone-related devices (e.g., flashers)	8 (0.8)	3,170 (3.5)	6 (1.0)	595 (1.1)	14 (0.9)	3,765 (2.6)
Closed caption T.V. or decoder	43 (4.1)	3,153 (3.5)	30 (5.1)	2,410 (4.6)	73 (4.5)	5,562 (3.9)
Amplifiers (e.g., FM, acoustic, infra-red)	44 (4.2)	5,322 (5.9)	22 (3.7)	4,758 (9.0)	66 (4.1)	10,080 (7.1)
Uses Earphones/ Headset	44 (4.2)	3,412 (3.8)	15 (2.5)	982 (1.9)	59 (3.6)	4,394 (3.1)
Visual or vibrating alarm	6 (0.6)	1,559 (1.7)	6 (0.1)	1,189 (2.3)	12 (0.7)	2,749 (1.9)
Cochlear implant	3 (0.3)	156 (0.2)	3 (0.5)	98 (0.2)	6 (0.4)	254 (0.2)
Another aid	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Do not know/No answer	1 (0.1)	37 (0.04)	0 (0.0)	0 (0.0)	1 (0.1)	37 (0.0)
Refused	0 (0.0)	0 (0.0)	1 (0.2)	170 (0.3)	1 (0.1)	170 (0.1)
Absolute N	1,037	90,131	592	52,678	1,629	142,809

Table E3: Participants' Self-rated Hearing.

Variable Self-rated Hearing		Male		Female		Total	
		N	%	N	%	N	%
Excellent	Raw	948	15	1,304	20.7	2,252	17.8
	Weighted	70,211	13.5	121,592	19.5	191,803	16.8
Very Good	Raw	1,809	28.5	2,086	33.1	3,895	30.8
	Weighted	150,830	29.1	197,296	31.6	348,127	30.5
Good	Raw	2,434	38.4	2,170	34.4	4,604	36.4
	Weighted	205,834	39.7	227,507	36.5	433,342	37.9
Fair	Raw	983	15.5	639	10.1	1,622	12.8
	Weighted	79,612	15.4	64,856	10.4	144,468	12.6
Poor	Raw	164	2.6	98	1.6	262	2.1
	Weighted	11,700	2.3	12,167	2	23,868	2.1
Don't Know/ No Answer	Raw	2	0	7	0.1	9	0.1
	Weighted	152	0	350	0.1	502	0

Table E4: Participants' $HT_{LowFreq}$ (dB), classified.

Variable			Male		Female		Total	
			N	%	N	%	N	%
$HT_{LowFreq}$ (dB)	<20 dB	Raw	2,768	43.7	2,700	42.8	5,468	43.2
		Weighted	215,564	41.6	241,833	38.8	457,397	40
	20-34.9	Raw	2,254	35.6	2,416	38.3	4,670	36.9
		Weighted	192,350	37.1	260,847	41.8	453,197	39.7
	35-49.9	Raw	842	13.3	752	11.9	1,594	12.6
		Weighted	70,280	13.6	77,106	12.4	147,386	12.9
	50-64.9	Raw	212	3.3	183	2.9	395	3.1
		Weighted	17,508	3.4	15,401	2.5	32,909	2.9
	65-79.9	Raw	37	0.6	35	0.6	72	0.6
		Weighted	2,591	0.5	2,527	0.4	5,117	0.4
	80-94.9	Raw	13	0.2	9	0.1	22	0.2
		Weighted	828	0.2	888	0.1	1,716	0.2
	95-99.9	Raw	6	0.1	3	0	9	0.1
		Weighted	214	0	133	0	347	0
	100-105	Raw	2	0	3	0	5	0
		Weighted	85	0	1,302	0.2	1,387	0.1

Table E5: Participants' $HT_{SpeechFreq}$ (dB), classified.

Variable			**Male**		**Female**		**Total**	
			N	%	N	%	N	%
$HT_{SpeechFreq}$ (dB)	<20 dB	Raw	1,314	20.7	2,010	31.9	3,324	26.3
		Weighted	101,244	19.5	174,577	28	275,821	24.1
	20-34.9	Raw	2,448	38.6	2,531	40.1	4,979	39.4
		Weighted	197,683	38.1	262,851	42.1	460,534	40.3
	35-49.9	Raw	1,700	26.8	1,192	18.9	2,892	22.9
		Weighted	144,290	27.8	127,634	20.5	271,924	23.8
	50-64.9	Raw	539	8.5	298	4.7	837	6.6
		Weighted	43,198	8.3	28,754	4.6	71,953	6.3
	65-79.9	Raw	101	1.6	49	0.8	150	1.2
		Weighted	10,833	2.1	3,784	0.6	14,617	1.3
	80-94.9	Raw	21	0.3	15	0.2	36	0.3
		Weighted	1,779	0.3	1,163	0.2	2,942	0.3
	95-99.9	Raw	10	0.2	4	0.1	14	0.1
		Weighted	387	0.1	172	0	559	0
	100-105	Raw	1	0	2	0	3	0
		Weighted	5	0	1,103	0.2	1,108	0.1

Table E6: Participants' $HT_{HighFreq}$ (dB), classified.

Variable			Male		Female		Total	
			N	%	N	%	N	%
$HT_{HighFreq}$ (dB)	<20 dB	Raw	164	2.6	480	7.6	644	5.1
		Weighted	10,485	2	37,928	6.1	48,412	4.2
	20-34.9	Raw	899	14.2	1,630	25.8	2,529	20
		Weighted	73,365	14.2	165,561	26.5	238,925	20.9
	35-49.9	Raw	1,359	21.4	1,775	28.1	3,134	24.8
		Weighted	109,687	21.2	170,457	27.3	280,143	24.5
	50-64.9	Raw	1,858	29.3	1,476	23.4	3,334	26.4
		Weighted	153,003	29.5	152,367	24.4	305,370	26.7
	65-79.9	Raw	1,368	21.6	578	9.2	1,946	15.4
		Weighted	112,092	21.6	59,125	9.5	171,217	15
	80-94.9	Raw	409	6.5	104	1.6	513	4.1
		Weighted	34,497	6.7	8,411	1.3	42,908	3.8
	95-99.9	Raw	33	0.5	17	0.3	50	0.4
		Weighted	1,908	0.4	1,390	0.2	3,298	0.3
	100-105	Raw	28	0.4	7	0.1	35	0.3
		Weighted	2,971	0.6	226	0	3,196	0.3

APPENDIX F: Social Determinants of Health

Table F1: Sexual orientation.

Variable Sexual orientation	**Male** **n** **(Column %)**		**Female** **n** **(Column %)**		**Total** **n** **(Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
Heterosexual (sexual relations with people of the opposite sex)	6,197 (97.8)	504,754 (97.4)	6,231 (98.8)	617,540 (99.0)	12,428 (98.3)	1,122,294 (98.3)
Homosexual, that is lesbian or gay (sexual relations with people of your own sex)	99 (1.6)	9781 (1.9)	43 (0.7)	3,691 (0.6)	142 (1.1)	13,472 (1.2)
Bisexual (sexual relations with people of both sexes)	26 (0.4)	2,849 (0.5)	13 (0.2)	1,031 (0.2)	39 (0.3)	3,879 (0.3)
Do not know/No answer	6 (0.1)	175 (0.0)	9 (0.1)	550 (0.1)	15 (0.1)	725 (0.1)
Refused	8 (0.1)	582 (0.1)	5 (0.1)	630 (0.1)	13 (0.1)	1,212 (0.1)
Absolute N	6,336	518,140	6,301	623,442	12,637	1,141,582
Missing	4 (0.1)	200 (0.0)	5 (0.1)	353 (0.1)	9 (0.1)	553 (0.0)

Table F2: Measures of frequency and percentage for Education.

Variable Education	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
No post-secondary degree, certificate, or diploma	489 (7.7)	49,674 (9.6)	551 (8.7)	583,556 (9.3)	1,040 (8.2)	108,030 (9.5)
Trade certificate or diploma from a vocational school or apprenticeship training	780 (12.3)	75,113 (14.5)	626 (9.9)	56,260 (9.0)	1,406 (11.1)	131,374 (11.5)
Non-university certificate or diploma from a community college, CEGEP, school of nursing, etc.	594 (9.4)	46,817 (9.0)	1,253 (19.9)	97,208 (15.6)	1,847 (14.6)	144,024 (12.6)
University certificate below bachelor's level	284 (4.5)	20,663 (4.0)	339 (5.4)	29,995 (4.8)	623 (4.9)	50,658 (4.4)
Bachelor's degree	1,291 (20.4)	50,652 (9.8)	1,126 (17.9)	47,479 (7.6)	2,417 (19.1)	98,130 (8.6)
University degree or certificate above bachelor's degree	1,801 (28.4)	70,995 (13.7)	919 (14.6)	39,246 (6.3)	2,720 (21.5)	110,240 (9.7)
Other	11 (0.2)	1,432 (0.3)	12 (0.2)	1,578 (0.2)	23 (0.2)	3,010 (0.3)
Do not know/ No answer	3 (0.0)	354 (0.1)	1 (0.0)	26 (0.0)	4 (0.0)	380 (0.0)
Absolute N	5,253	315,698	4,827	330,148	10,080	645,846
Missing, n (%)	1,087 (17.1)	202,642 (39.1)	1,479 (23.4)	293,647 (47.1)	2,566 (20.3)	496,289 (43.4)

Table F3: Participant's Cultural Background Frequencies (CLSA terminology for cultural background).

Variable	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
Cultural	Raw	Weighted	Raw	Weighted	Raw	Weighted
White	6,076 (94.8)	492,933 (94.1)	6,126 (96.3)	603,820 (96.1)	12,202 (95.6)	1,096,753 (95.2)
Chinese	37 (0.6)	5,470 (1.0)	26 (0.4)	2,463 (0.4)	63 (0.5)	7,933 (0.7)
South Asian	91 (1.4)	8,764 (1.7)	26 (0.4)	1,187 (0.2)	117 (0.9)	9,952 (0.9)
Black	53 (0.8)	4,680 (0.9)	49 (0.8)	8,101 (1.3)	102 (0.8)	12,780 (1.1)
Filipino	5 (0.1)	363 (0.1)	9 (0.1)	622 (0.1)	14 (0.1)	985 (0.1)
Latin American	15 (0.2)	1,595 (0.3)	11 (0.2)	2,414 (0.4)	26 (0.2)	4,009 (0.3)
Southeast Asian	11 (0.2)	517 (0.1)	11 (0.2)	1,520 (0.2)	22 (0.2)	2,038 (0.2)
Arab	19 (0.3)	1,107 (0.2)	4 (0.1)	200 (0.0)	23 (0.2)	1,307 (0.1)
West Asian	5 (0.1)	190 (0.0)	1 (0.0)	36 (0.0)	6 (0.0)	226 (0.0)
Japanese	11 (0.2)	1,038 (0.2)	7 (0.1)	507 (0.1)	18 (0.1)	1,546 (0.1)
Korean	3 (0.0)	160 (0.0)	0 (0.0)	0 (0.0)	3 (0.0)	160 (0.0)
North American Indian	33 (0.5)	2,631 (0.5)	38 (0.6)	3,485 (0.6)	71 (0.6)	6,117 (0.5)
Inuit	0 (0.0)	0 (0.0)	1 (0.0)	99 (0.0)	1 (0.0)	99 (0.0)
Métis	14 (0.2)	1,008 (0.2)	19 (0.3)	1,776 (0.3)	33 (0.3)	2,784 (0.2)
Other	28 (0.4)	2,649 (0.5)	26 (0.4)	1,874 (0.3)	54 (0.4)	4,523 (0.4)
Don’t know/No answer	9 (0.1)	873 (0.2)	5 (0.1)	237 (0.0)	14 (0.1)	1,109 (0.1)
Refused	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Missing	4 (0.1)	200 (0.0)	5 (0.1)	353 (0.1)	9 (0.1)	553 (0.0)

Table F4: Parental Ethnic Background Frequencies (CLSA terminology for ethnicity).

Ethnicity	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
English	2,496 (22.9)	163,967 (18.6)	2,464 (21.7)	197,530 (17.7)	4,960 (22.3)	361,497 (18.1)
Canadian	1,741 (16.0)	185,155 (21)	1,857 (16.4)	232,412 (20.8)	3,598 (16.2)	417,567 (20.9)
Scottish	1,422 (13)	94,712 (10.7)	1,552 (13.7)	122,542 (11)	2,974 (13.4)	217,254 (10.9)
Irish	1,264 (11.6)	77,639 (8.8)	1,506 (13.3)	117,556 (10.5)	2,770 (12.5)	195,195 (9.8)
French	1,096 (10.1)	126,195 (14.3)	1,276 (11.2)	173,563 (15.6)	2,372 (10.7)	299,758 (15)
North American Indian	91 (0.8)	6,084 (0.7)	140 (1.2)	15,501 (1.4)	231 (1.0)	21,585 (1.1)
Welsh	204 (1.9)	10,525 (1.2)	189 (1.7)	18,794 (1.7)	393 (1.8)	29,319 (1.5)
German	699 (6.4)	51,159 (5.8)	712 (6.3)	69,036 (6.2)	1,411 (6.3)	120,195 (6)
Hebrew	86 (0.8)	6,291 (0.7)	83 (0.7)	8,933 (0.8)	169 (0.8)	15,224 (0.8)
Italian	128 (1.2)	13,053 (1.5)	100 (0.9)	20,307 (1.8)	228 (1.0)	33,360 (1.7)
Inuit	2 (0.0)	43 (0.0)	4 (0.0)	178 (0.0)	6 (0.0)	222 (0.0)
Métis	28 (0.3)	1,968 (0.2)	28 (0.2)	2,831 (0.3)	56 (0.3)	4,799 (0.2)
Dutch	271 (2.5)	20,221 (2.3)	242 (2.1)	22,316 (2)	513 (2.3)	42,537 (2.1)
Norwegian	97 (0.9)	7,631 (0.9)	102 (0.9)	7,803 (0.7)	199 (0.9)	15,434 (0.8)
South Asian	109 (1.0)	10,205 (1.2)	44 (0.4)	2,746 (0.2)	153 (0.7)	12,951 (0.6)
Swedish	98 (0.9)	7,348 (0.8)	93 (0.8)	7,374 (0.7)	191 (0.9)	14,722 (0.7)
Ukrainian	207 (1.9)	19,273 (2.2)	192 (1.7)	18,737 (1.7)	399 (1.8)	38,010 (1.9)
Chinese	39 (0.4)	5,625 (0.6)	32 (0.3)	2,754 (0.2)	71 (0.3)	8,379 (0.4)
Portuguese	17 (0.2)	1,688 (0.2)	14 (0.1)	1,297 (0.1)	31 (0.1)	2,985 (0.1)
Other	776 (7.1)	70,241 (8)	674 (5.9)	69,614 (6.2)	1,450 (6.5)	139,855 (7)
Do not know	30 (0.3)	2,566 (0.3)	38 (0.3)	3,094 (0.3)	68 (0.3)	5,659 (0.3)
Refused	0 (0.0)	0 (0.0)	2 (0.0)	54 (0.0)	2 (0.0)	54 (0.0)

Ethnicity	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
Absolute N	6,301	881,587	6,258	1,114,974	12,559	1,996,562
Missing, n (%)	39 (0.6)	2405 (0.5)	48 (0.8)	4044 (0.6)	87 (0.7)	6449 (0.6%)

Table F5: Measures of frequency and percentage for Total Household income.

Variable Total Household Income	**Male n (Column %)**		**Female n (Column %)**		**Total n (Column %)**	
	Raw	Weighted	Raw	Weighted	Raw	Weighted
Less than $20,000	235 (3.7)	25,470 (4.9)	576 (9.1)	75,166 (12)	811 (6.4)	100,636 (8.8)
$20,000 or more, but less than $50,000	1,583 (25)	163,546 (31.6)	2,332 (37)	249,116 (39.9)	3,915 (31)	412,662 (36.1)
$50,000 or more, but less than $100,000	2,598 (41)	195,080 (37.6)	1,936 (30.7)	162,813 (26.1)	4,534 (35.9)	357,893 (31.3)
$100,000 or more, but less than $150,000	989 (15.6)	65,282 (12.6)	516 (8.2)	41,463 (6.6)	1,505 (11.9)	106,744 (9.3)
$150,000 or more	542 (8.5)	38,321 (7.4)	211 (3.3)	19,633 (3.1)	753 (6)	57,955 (5.1)
Don’t know/No answer	128 (2)	7,821 (1.5)	353 (5.6)	35,748 (5.7)	481 (3.8)	43,569 (3.8)
Refused	265 (4.2)	22,821 (4.4)	382 (6.1)	39,855 (6.4)	647 (5.1)	62,677 (5.5)
Absolute N	6,340	518,340	6,306	623,795	12,646	1,142,135
Missing	0	0	0	0	0	0