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Dizziness and imbalance and their association with general and mental health in a community-based cross-sectional study of middle-aged individuals: the Busselton healthy ageing study

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Abstract

Background Dizziness and imbalance are common symptoms among patients visiting healthcare providers. Current knowledge about their prevalence, impact on daily life, and associated factors is primarily based on selected samples from individuals seeking medical help, particularly older individuals. This study aimed to estimate the prevalence, symptoms, and impact of dizziness or imbalance symptoms, and to assess the association between these symptoms and their characteristics with demographic, general health, and mental health factors in middle-aged men and women from a representative, general population sample.

Methods Cross-sectional data were collected from participants aged 45 to 70 years in the Busselton Healthy Ageing Study (BHAS), recruited in the City of Busselton, Western Australia. The data included physical tests and health-related questionnaires covering demographics, medical history, general and mental health, including any dizziness and imbalance symptoms and their impact on daily life. Estimates were made of the prevalence, patterns, and impact of dizziness and imbalance symptoms. Logistic regression was employed to calculate the association between demographic, mental and general health (independent variables) and the presence of dizziness or imbalance symptoms (dependent variable). Adjustments were made for sex and age as confounding factors.

Results Of the 5086 participants, 1216 (23.9%) reported imbalance or dizziness, with light-headedness the most common type (64.3%; 782 of 1216). For nearly half (565; 46.5%) the imbalance or dizziness occasionally effected daily life, while for some, the impact was frequent ($n=50$, 4.1%) or constant ($n=15$, 1.2%). Being female (adjusted OR 2.05, 95%CI 1.79–2.34) and older in age (in years; adjusted OR 1.02, 95%CI 1.00-1.03), having a history of general health issues, and experiencing mental health problems or mental health symptoms were significantly associated with dizziness or imbalance symptoms.

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Conclusions Dizziness or imbalance are common symptoms among individuals aged 45 to 70 years and are associated with older age, being female, and poorer general and mental health. Given that approximately half of those affected reported occasional effects on daily life, with a few reporting frequent or constant effects, the outcomes of the study could help to raise awareness among healthcare providers about the prevalence, symptoms, and associated conditions.

Keywords Dizziness, Imbalance, General health, Mental health, General population

Background

Dizziness, imbalance and vertigo are commonly reported symptoms in both the general population as well in healthcare practice [1–3]. Studies have shown that dizziness and/or vertigo rank among the top three health-related problems in patients visiting general outpatient clinics [4, 5], and account for 2.5% of all visits to emergency healthcare services [6] and 10% of all neurological consultations in the Western world [7]. While the term dizziness is commonly used to describe a wide range of sensations, the specific pattern of symptoms can help differentiate those with true spinning vertigo problems from those with non-vertiginous symptoms (dizziness, lightheadedness, imbalance, unsteadiness, motion intolerance) [8]. However, the natures of symptoms often do not to directly correlate with a specific underlying condition, making it difficult for healthcare providers to identify the core problem or associated diseases.

Dizziness can have a major impact on daily life, negatively affecting mobility, induce fear or psychological concerns [9], increase the risk of falls and hospitalization, and reducing overall quality of life [10, 11]. Dizziness and imbalance may result from the effects of (poly)pharmacy, disruptions of the labyrinth, or central nervous, cardiovascular, visual system, metabolic or psychological disorders [12]. The symptoms are generally considered a multifactorial health condition, arising from the cumulative effects of multiple system distortions or deficits [1, 2].

Currently, substantial health care resources are allocated to the diagnosis and management of dizziness and imbalance symptoms [13] and these costs are expected to increase with the ageing of the population.

Most knowledge of the prevalence and associated factors for dizziness or imbalance symptoms is based on studies of people aged 65 years and older, a group who often interact with the health system, and often characterised by a high prevalence of multi-morbidities [14–17]. However, limited data are available on the prevalence and associated factors in younger age groups, such as middle-aged adults under 65 years, within the general population.

In a German community survey that included people aged 14 to 90 years, 15.8% reported experiencing symptoms of dizziness in the past month [18]. Similarly, in a French community study of individuals aged 18–86 years found the 1-year prevalence for dizziness during the last year was 35.6%, based on questionnaire data [19]. Other studies have also highlighted the prevalence of dizziness, with a lifetime prevalence of dizziness of 42% reported in a random sample of the adult population in São Paulo, Brazil, using questionnaires about dizziness experienced in the past month [20]. Additionally, a study of an adult German residential population reported a lifetime prevalence of moderate or severe dizziness or vertigo to be 29.5%, based on telephone interviews [21].

Some of these population-based studies have also assessed dizziness and its associated factors. Evidence from these studies suggest an association between dizziness or imbalance and increasing age [5, 21, 22]. Furthermore, female gender, cardiometabolic diseases and mental health diseases have been identified as factors associated with dizziness [5, 18]. However, these studies often lack comprehensive analysis of its impact or include a limited set of measures included in their analyses. For example, in the German study, mental health was only in terms of on symptoms of panic and anxiety, and general health was assessed using a restricted list of current health conditions, without considering previous diagnoses or physical signs of health conditions [18].

To date, data there is limited data on the prevalence and impact of dizziness or imbalance, as well as on associated demographic and health related measures, in middle-aged adults. This population is at an increased risk of developing new conditions associated with aging, although these symptoms have usually not led to the development of a wide range of comorbidities [23, 24]. Understanding these aspects is important for designing strategies to mitigate negative consequences and for developing healthcare programs aimed at addressing dizziness-related disabilities in an early stage.

Therefore, the aim of this study was to examine the prevalence of dizziness or imbalance symptoms, and the reported effect on daily life as experienced by individuals. Additionally, the study sought to assess the association between demographics, general and mental health, and the symptoms of dizziness or imbalance, and to compare factors based on the nature of symptoms in a sample of middle-aged males and females in a general population.

Methods

This study was reported according to the STROBE statement [25].

Study setting and participants

Data were obtained from the Busselton Healthy Ageing Study (BHAS) [26]. The BHAS aims to identify the cumulative effects of multimorbidity that impact on healthy aging; the full protocol of the study, including all measurements, is described elsewhere [26]. The Busselton Shire accounts for about 1.25% of the Western Australian population (25,355 people according to the 2006 Australian Census). Of those 6690 adults born between 1946 and 1964, residing in the City of Busselton, Western Australia, and listed on the electoral roll in the region, all were invited to participate in this population-based study. Invitations to participate were issued in a randomized order, with recruitment efforts focused on sequential 10% sample draws. Of the 6690 adults invited, 5107 agreed to participate (response rate 76.3%).

For the current study, cross-sectional data collected between May 2010 and December 2015 was used, resulting in a cohort of 5086 participants aged 45 to 70 years. Participants were invited to attend the testing centre for a four-hour appointment, during which they completed health-related questionnaires and underwent comprehensive physical and cognitive assessments.

The study was conducted according to the Declaration of Helsinki and was approved by The University of Western Australia Human Research Ethics Committee (Number RA/4/1/2203). All participants gave their informed written consent before inclusion in the study.

Outcome assessment; subjective and objective outcomes

Subjective data on the symptoms of dizziness and imbalance, their effect of these on daily life, as well as mental and general health-related symptoms, diseases, and procedures were collected using a self-administered clinical history questionnaire that was completed by all participants who attended the testing centre. Objective data of general health, including anthropometry and blood pressure, were gathered from physical assessments conducted at the study centre. During this visit, a fasting venous blood sample was collected for biochemistry testing and analysed for biochemical measures, as described in James et al. [26].

Demographics

Demographic data included age at the time of assessment, sex, highest educational level obtained, and yearly household income in Australian dollar (AUD).

Dizziness and imbalance outcome assessment

The main outcome of this study was the question concerning dizziness or imbalance: *"Do you experience any imbalance or dizziness?" (no, yes).*

To describe the characteristics of the dizziness or imbalance in more detail, if *"yes"* was answered, further questions and answer options were included:

"What is the nature of your imbalance or dizziness?" (spinning or sensation of movement/ light-headedness/ unsteadiness on feet);
"How often do you experience this imbalance or dizziness?" (daily, weekly, monthly, less frequent than monthly);
"How long do the specific episodes of imbalance or dizziness last" (seconds to less than 2 min, 2 to 20 min, over 20 min to hours, hours to days);
"How long do the after-effects of feeling unwell or off-colour last?" (no after-effects, minutes, hours, days);
"Do you suffer from any of the following symptoms for more than 20 minutes that you associate with your dizziness or imbalance? " (fullness(blockage) in the ears, tinnitus, reduced hearing, nausea, vomiting);
"Does your dizziness or imbalance occur when, sitting, walking, sneezing, straining, bending down, hearing a loud noise, looking up to a high shelf, lying down and rolling over to one side, standing up? ".

The effect on daily life of the experienced dizziness or imbalance was scored with the question *'How often does your dizziness or imbalance affect your daily life and activities? (not at all, occasionally, frequently, constantly)'.*

Measures of general health

As part of the questionnaire, participants were asked whether their doctor had informed them that they had a high blood pressure and whether they were using drugs for hypertension. Based on this subjective information participants were classified as having hypertension if they self-reported high blood pressure or reported taking drugs for hypertension.

Participants were categorized as having cardiovascular disease if they reported any of the following conditions or procedures: angina, having a cardiac pacemaker/ implant, myocardial infarction, coronary bypass or stent placement. Similarly, a stroke was scored if participants indicated that their doctor had diagnosis them with a transient ischemic attack (TIA), stroke, or underwent carotid surgery.

Peripheral artery disease (PAD) was indicated by an ankle brachial index (ABI) of less than 0.9 in either leg. If ABI measurement was missing, PAD was determined by a positive history of having claudication.

Blood pressure was measured with the participant supine, after five minutes of rest. Systolic and diastolic blood pressures (MAP) were measured using a vascular profiler (Omron VP1000). Blood pressure was scored in stages according to the classification of the American Heart Association (AHA). These stages were based on systolic (SBP) and diastolic blood pressure (DBP) levels, as normal (SBP < 120 mm Hg & DBP < 80 mm Hg), elevated (SBP ≥ 120-<130 mm Hg & DBP < 80 mm Hg), hypertension stage 1 (SBP ≥ 130-<140 mm Hg or DBP ≥ 80-<90 mm Hg) or hypertension stage 2 (SBP ≥ 139 mm Hg or DBP > 89 mm Hg) [27]. Standing height and weight were measured with the participant lightly clothed and shoeless using standard anthropometric techniques. Body Mass Index (BMI) was calculated based on height and weight.

As part of the questionnaire, participants were asked whether their doctor had informed them that they had thyroid disease or diabetes. In addition, a fasting venous blood sample was collected for biochemistry testing. These tests included general plasma chemistry (Fasting Plasma Glucose; FPG) and whole blood (glycated haemoglobin; HbA1c). The criteria of the American Diabetes Association (ADA) 2019 were used to classify participants as having diabetes or pre-diabetes based on FPG and HbA1c results (diabetes; glycated haemoglobin > 6.5% or fasting plasma glucose > 7.0 mmol/L®; pre-diabetes; glycated haemoglobin 5.7–6.4% or fasting plasma glucose 5.6–6.9 mmol/L) [28].

Besides these cardiometabolic measures, participants were asked whether their doctor had informed them that they had one of the following other general health conditions: chronic ear infection, Meniere's disease, migraine, and "*Do you have a hearing impairment?" (Yes/No).*

Lastly, self-reported general health rating, long standing disability or illness, and the impact of physical function on daily activities, were assessed using the Short Form SF-12 subscales, specifically the Physical Component Summary (PCS). The SF-12 evaluates the following physical health-related domains through six questions: General Health (GH), Physical Functioning (PF), Role Physical (RP), and Body Pain (BP). PCS subscale summary scores range from 0 (lowest physical health level) to 100 (highest level) [29].

Measures of mental health

Mental health was measured by the question '*Have you ever been told by a doctor that you have depression*' and '*Have you ever been given advice or treatment for your depression*'. The 9-item Patient Health Questionaire-9 (PHQ-9) was used to score the presence of a depressive disorder against DSM-IV criteria [30] (none, other depressive disorder or major depressive disorder) as well as depression severity (levels of severity; score 1–4 = minimal depression; 5–9 = mild depression; 10–14 = moderate depression; 15–19 = moderately severe depression and 20–27 = severe depression) [31]. The impact of mental function on daily activities were assessed using the six questions of the SF-12 subscale Mental Component Summary (MCS). This included Vitality (VT), Social Functioning (SF), Role Emotional (RE), and Mental Health (MH). Summary scores of the MCS range from 0 (lowest mental health level) to 100 (highest level) [29]. The validated 21 item-Depression and Anxiety and Stress Scale (DASS21) was used to measure the emotional states of depression, anxiety and stress. Published cut-off scores were used for levels of severity [32].

Statistical analyses

Dizziness and imbalance symptoms, along with their effects on daily life, were reported descriptively. Demographic variables and measures of general and mental health were analysed in relation to the presence of dizziness or imbalance symptoms, as well as the nature of the dizziness or imbalance symptoms. Mean and standard deviation (SD) were used for continuous variables, while numbers and percentages were used for categorical variables. A complete case analysis was performed.

Univariate logistic regression was used to calculate the odds ratio (OR) and the associated 95% confidence interval to express the association between demographics, mental and general health measures (independent) and the presence of dizziness or imbalance symptoms (dependent variables). Additionally, univariate logistic regression was used to analyse the association between the aforementioned independent variables and the specific categories of the nature of dizziness or imbalance (spinning or sensation of movement or light-headedness or unsteadiness on feet) (dependant variables) by comparing these toe other symptoms of dizziness and imbalance. Box-Tidwell tests were conducted to test the assumptions of linearity of the logistic regression model.

To assess the generalizability of the outcomes of the studied sample to the general population, the age and sex distributions of the studied sample were compared with that of the Busselton population using Census data from the Australian Bureau of Statistics [33]. If differences were identified, risk analyses were adjusted for both factors by multivariate logistic regression. IBM SPSS statistics version 27.0 was used for statistical analyses. A value of $p < 0.05$ was considered statistically significant.

Results

Characteristics of studied sample

Of the total study sample of 5107 participants who initially agreed to participate, 5086 participants provided data for this study and were included in this study ($n = 21$,

0.4% missing). Of these, 2296 participants (45.1%) were male, and 2790 (54.9%) were female, with a mean age of 58.0 (SD 5.8) years. Participants in the BHAS study were older than the general population of Busselton, and more female than males participated compared to population proportions (Table 1). As a result, the outcomes were adjusted for age and sex.

Symptoms of imbalance or dizziness

Of the 5086 participants, 1216 (23.9% (95%CI 22.7–25.1)) reported experiencing imbalance or dizziness. Among these, two-thirds reported sensations of light-headedness ($n = 782$, 64.3% (95%CI 61.6–67.0)), one-third sensations of spinning or movement ($n = 449$, 36.9% (95%CI 34.2–40.0)) and one-third unsteadiness on their feet ($n = 432$, 35.5% (95% CI 32.9–38.3)) (Table 2).

Most participants reported that the frequency of their imbalance or dizziness symptoms to be less then monthly ($n = 690$, 56.7% (95% CI 53.9%-59.6%)), symptoms to be present for seconds to less than 2 min ($n = 956$, 78.6% (95% CI 76.6%-80.8%)), without any after-effects ($n = 729$, 60.0% (95%CI 57.2–62.7%) and that nausea was the most common accompanying symptom ($n = 223$, 18.3% (95%CI 16.3-20.6%)).

Approximately half of the participants with dizziness or imbalance reported occasional effects on daily life and activities ($n = 565$, 46.5% (95%CI 43.7-49.3%)). A small proportion reported frequent effects ($n = 50$, 4.1% 95%CI 3.1-5.4%)) or a constant effect ($n = 15$, 1.2% 0.7-2.0%)) on their daily life and activities. The remainder ($n = 561$, 46.1% 95%CI 43.3–48.9)) reported no effects on their daily life or activities.

Demographics, general and mental health outcomes of the studied population

Tabulated scores for demographics, general health, and mental health outcomes can be found in Tables 3, 4 and 5, respectively. A diagnosis of hypertension or use of blood pressure medication was reported by 41.4% ($n = 2108$) of participants. Measured blood pressure indicated actual hypertension in 57.3% ($n = 2913$) (AHA stage 1 or 2).

A diagnosis of diabetes mellitus (DM) was reported by 6.5% ($n = 332$) participants. Blood chemistry test data identified 5.2% ($n = 263$) with DM and 45.0% ($n = 2287$) with blood glucose levels indicating pre-DM. A history of migraine was reported by 17.6% ($n = 893$), while 19.2% ($n = 2287$) reported hearing impairment.

For mental health outcomes, 26.7% ($n = 1358$) reported being diagnosed with depression. The majority scored within the normal range on the DASS-21 scale for depression (74.3%, $n = 3777$), anxiety (72.5%, $n = 3688$) and stress (62.7%, $n = 3190$).

Association between demographics, general and mental health and imbalance or dizziness symptoms

Assumptions of a linear relationship between the dependant and independent outcomes were met by Box-Tidwell testing. Being female (adjusted OR 2.05, 95%CI 1.79–2.34), having a higher age (in years; adjusted OR 1.02, 95%CI 1.00-1.03) and having a household income of < AUD$20,000 (adjusted OR 1.61, 95% CI 1.21–2.15) were all statistically significantly related to experiencing imbalance or dizziness (Table 3). Those with a history of thyroid disease (adjusted OR 1.36, 95% CI 1.10–1.70), diabetes (adjusted OR 1.35, 95%CI 1.05–1.74), stroke (adjusted OR 2.14, 95% CI 1.43–3.21), heart disease (adjusted OR 1.88, 95%CI 1.37–2.59), a higher BMI (per point: adjusted OR 1.02, 95% CI 1.01–1.04), and a history of chronic ear infections (adjusted OR 1.93, 95% CI 1.52–2.44), Meniere's disease (adjusted OR 7.55, 95% CI 4.10-13.91), migraine (adjusted OR 1.67, 95% CI 1.42–1.96) and self-reported hearing impairment (adjusted OR 2.50, 95% CI 1.88–3.34) were all found to be significantly associated with having symptoms of dizziness or imbalance (Table 3).

Having a diagnosis of depression (adjusted OR 1.76, 95% CI 1.53–2.03), PHQ9 scores indicating another depressive disorder (adjusted OR 2.45, 95% CI 1.66–3.62) and a major depressive disorder (adjusted OR 3.51, 95%

Table 1 Characteristics of sex and age in the studied sample

	Studied sample			**Population statistics Busselton**		
Age category (yrs)	Male N (% of total male)	Female N (% of total female)	Total N (% of total)	Male N (% of total male)	Female N (% of total female)	Total N (% of total)
45–49	237 (10.3)	284 (10.2)	521 (10.2)	1028 (22.6)	1095 (22.4)	2123 (22.5)
50–54	542 (23.6)	686 (24.6)	1228 (24.1)	953 (20.9)	1083 (22.1)	2036 (21.5)
55–59	574 (25.0)	714 (25.6)	1288 (25.3)	924 (20.3)	1020 (20.8)	1944 (20.6)
60–64	625 (27.2)	764 (27.4)	1389 (27.3)	919 (20.2)	925 (18.9)	1844 (19.5)
65–70	318 (13.9)	342 (12.3)	660 (13.0)	731* (16.0)	772* (15.8)	1503* (15.9)
Total	**2296 (45.1)**	**2790 (54.9)**	**5086 (100)**	**4555 (48.2)**	**4895 (51.8)**	**9450 (100)**

Characteristics of sex and age in the studied sample and in the population of Busselton using Census data from the Australian Bureau of Statistics [33]. * Numbers are based on data for the age category 65–69 years. Yrs: years; N: number

Table 2 Characteristics of imbalance or Dizziness symptoms in studied sample

Description	N (%) (*n* = 1216)
Nature	
- Spinning/sensation of movement	449 (36.9)
- Light-headedness	782 (64.3)
- Unsteadiness on feet	432 (35.5)
- Missing	0 (0)
How often	
- < monthly	690 (56.7)
- Monthly	195 (16.0)
- Weekly	202 (16.6)
- Daily	123 (10.1)
- Missing	6 (0.5)
How long	
- Seconds - < 2 min	956 (78.6)
- 2 to 20 min	114 (9.4)
- > 20 min to hours	61 (5.0)
- Hours to days	84 (6.9)
- Missing	1 (0.1)
Duration of after-effects	
- No after-effects	729 (60.0)
- Minutes	280 (23.0)
- Hours	133 (10.9)
- Days	66 (5.4)
- Missing	8 (0.7)
Associated symptoms	
- Fullness	112 (9.2)
- Tinnitus	126 (10.4)
- Reduced hearing	95 (7.8)
- Nausea	223 (18.3)
- Vomiting	47 (3.9)
- Missing	47 (3.9)
Occurrence when	
- Sitting	231 (19.0)
- Walking	324 (26.6)
- Sneezing	499 (41.0)
- Straining	109 (9.0)
- Bending down	242 (19.9)
- Hearing a loud noise	42 (3.5)
- Looking up to a high shelf	61 (5.0)
- Lying down and rolling over to one side	14 (1.2)
- Standing up	677 (55.7)
- Missing	7 (0.6)
Affect daily life and activities	
- Not at all	561 (46.1)
- Occasionally	565 (46.5)
- Frequently	50 (4.1)
- Constantly	15 (1.2)
- Missing	25 (2.1)

Characteristics of symptoms of participants reporting dizziness and imbalance symptoms out of the total study sample. N: number,

CI 2.43–5.05), and having higher DASS21 depression, anxiety and stress scores were all associated with symptoms of dizziness or imbalance (Table 5).

Association between demographics, general and mental health and nature of imbalance or dizziness

For participants experiencing spinning or a sensation of movement associated with their imbalance or dizziness (*n* = 449, 36.9%), symptoms were significantly associated with being female (adjusted OR 1.78, 95% CI 1.37–2.31), having a history of Meniere's disease (adjusted OR 3.94, 95% CI 1.94–7.99) and having a diagnosis of depression (adjusted OR 1.31, 95%CI 1.03–1.67) (Tables 3, 4 and 5).

Participants who reported light-headedness (*n* = 782, 64.3%) were younger (per year; adjusted OR 0.98, 95% CI 0.96-1.00), less likely to report primary school as their highest education level (adjusted OR 0.35, 95% CI 0.13–0.99), and less likely to have hypertension (AHA stage 1; adjusted OR 0.65, 95% CI 0.47–0.91) (Tables 3, 4 and 5).

Participants experiencing unsteadiness on their feet (*n* = 432, 35.5%) was found to be older (adjusted OR 1.04, 95% CI 1.02–1.06) and more likely to have diagnosed hypertension (adjusted OR 1.49, 95% CI 1.16–1.90), diagnosed diabetes (adjusted OR 1.59, 95% CI 1.05–2.43), higher BMI scores (adjusted OR 1.06, 95% CI 1.03–1.08), lower general health scores (SF12 PCS adjusted OR 0.96, 95% CI 0.95–0.97), a history of migraine (adjusted OR 1.51, 95% CI 1.15–1.97), hearing impairment (adjusted OR 1.70, 95% CI 1.29–2.23), and having higher mental health scores (PHQ9 major depression scores, DASS21 depression, anxiety and stress scores) (Tables 3, 4 and 5).

Discussion

In this population-based cohort study of individuals aged 45 to 70 years, nearly a quarter of participants experienced imbalance or dizziness, most commonly reported as light-headedness. The majority reported no or an occasional effect of these symptoms on their daily life and activities. Several demographics, general health, and mental health-related variables were found to be associated with imbalance, dizziness or the described nature of these experience.

The estimated prevalence of dizziness or imbalance of 23.9% found in our study of middle-aged people, is somewhat different from the limited data reported in other community-based studies covering broader age ranges [1, 18, 19]. This discrepancy may be explained not only by differences in study settings or populations, but also by variations in the definitions or descriptions of dizziness or imbalance used in studies [1]. For example, a community-based study of people aged 18 to 86 years by Bisdorff et al., found a 1-year prevalence of 48.3% for vertigo, 39.1% for unsteadiness, and 35.6% for dizziness [19]. In our study we did not define a specific time frame for the

Table 3 Outcomes of association between Dizziness or imbalance and its nature and demographics

	imbalance or dizziness (*N* = 5086)			**Outcomes of those with imbalance or dizziness by nature of symptoms (*N* = 1216)**								
				Spinning/sensation of movement			**Light-headedness**			**Unsteadiness on feet**		
	Yes N (%)	**OR (95%CI)**	**Adjusted OR (95%CI)**	**Yes N (%)**	**OR (95%CI)**	**Adjusted OR (95%CI)**	**Yes N (%)**	**OR (95%CI)**	**Adjusted OR (95%CI)**	**Yes N (%)**	**OR (95%CI)**	**Adjusted OR (95%CI)**
Total (Missing *n* = 5)	1216 (23.8)			449 (36.9)			782 (64.3)			432 (35.5)		
Age years[#] (Missing *n* = 0)	58.4 (5.9)	**1.01 (1.00-1.03)**	**1.02 (1.00-1.03)**	58.0 (5.9)	0.98 (0.96-1.00)	0.99 (0.97–1.01)	58.0 (6.0)	**0.98 (0.96-1.00)**	**0.98 (0.96-1.00)**	59.1 (5.9)	**1.04 (1.02–1.06)**	**1.04 (1.02–1.06)**
Sex												
Male (ref)	392 (32.2)	—	—	110 (24.5)	—	—	246 (31.5)	—	—	147 (34.0)	—	—
Female (Missing *n* = 0)	824 (67.8)	**2.04 (1.78–2.33)**	**2.05 (1.79–2.34)**	339 (75.5)	**1.79 (1.38–2.32)**	**1.78 (1.37–2.31)**	536 (68.5)	1.11 (0.86–1.42)	1.09 (0.85–1.40)	285 (66.0)	0.88 (0.69–1.13)	0.90 (0.70–1.16)
Average Income (AUD)												
None of above	6 (0.5)	1.71 (0.65–4.50)	1.42 (0.53–3.76)	3 (0.7)	1.72 (0.34–8.70)	1.65 (0.32–8.47)	2 (0.3)	0.33 (0.06–1.84)	0.33 (0.06–1.82)	1 (0.2)	0.45 (0.05–3.93)	0.46 (0.5–4.02)
< 20,000 $	103 (8.5)	**2.04 (1.55–2.70)**	**1.61 (1.21–2.15)**	37 (8.2)	0.96 (0.59–1.56)	0.91 (0.55–1.50)	70 (9.0)	1.40 (0.86–2.29)	1.62 (0.98–2.69)	51 (11.8)	**2.21 (1.37–3.56)**	**2.01 (1.23–3.29)**
20,001–60,000 $	420 (34.5)	**1.33 (1.11–1.59)**	1.15 (0.95–1.39)	151 (33.6)	0.96 (0.69–1.35)	0.96 (0.68–1.36)	272 (34.8)	1.22 (0.87–1.69)	1.38 (0.98–1.95)	168 (38.9)	**1.50 (1.07–2.11)**	1.37 (0.96–1.95)
60,001-100,000 $	293 (24.1)	1.19 (0.98–1.45)	1.12 (0.92–1.36)	111 (24.7)	1.05 (0.73–1.50)	1.01 (0.71–1.45)	189 (24.2)	1.20 (0.84–1.72)	1.25 (0.87–1.79)	93 (21.5)	1.15 (0.72–1.52)	1.03 (0.71–1.49)
> 100,000 $ (ref)	231 (19.0)	—	—	85 (18.9)	—	—	139 (17.8)	—	—	71 (16.4)	—	—
Prefer not to say (Missing *n* = 0)	162 (13.3)	**1.32 (1.05–1.66)**	1.12 (0.88–1.42)	61 (13.6)	1.04 (0.69–1.57)	0.99 (0.65–1.53)	109 (13.9)	1.36 (0.89–2.07)	1.54 (1.00-2.38)	48 (11.1)	0.95 (0.61–1.47)	0.87 (0.55–1.37)
Highest education												
No school	1 (0.1)	NA	NA	0 (0.0)	NA	NA	1 (0.1)	NA	NA	0 (0.0)	NA	NA
Prim. School	16 (1.3)	0.95 (0.54–1.67)	0.94 (0.53–1.67)	3 (0.7)	0.42 (0.12–1.47)	0.44 (0.12–1.58)	6 (0.8)	**0.32 (0.12–0.90)**	**0.35 (0.13–0.99)**	8 (1.9)	1.85 (0.69-5.00)	1.60 (0.59–4.34)
Sec. School (ref)	610 (50.2)	—	—	218 (48.6)	—	—	397 (50.8)	—	—	214 (49.5)	—	—
Other educ.	372 (30.6)	0.98 (0.85–1.14)	0.98 (0.85–1.14)	141 (31.4)	1.10 (0.84–1.43)	1.05 (0.80–1.38)	242 (30.9)	1.00 (0.76–1.31)	0.97 (0.74–1.27)	132 (30.6)	1.02 (0.78–1.33)	1.07 (0.81–1.41)
University (Missing *n* = 0)	216 (17.8)	0.87 (0.73–1.04)	0.87 (0.73–1.04)	86 (19.2)	1.19 (0.87–1.64)	1.14 (0.83–1.58)	135 (17.3)	0.89 (0.65–1.23)	0.86 (0.62–1.19)	78 (18.1)	1.05 (0.76–1.45)	1.10 (0.80–1.54)

Outcomes of univariate analysis of the association between experienced dizziness or imbalance and its nature in relation to demographics. Values reported in n (%) or mean (SD) when indicated by [#]; AUD = Australian Dollar; OR = Odds Ratio, CI = Confidence Interval. N = number; ref = reference category; NA = not applicable by too low cases in the equation. Significant outcomes with p-values ($p < 0.05$) are depicted bold

experiences of dizziness or imbalance, but instead asked the participants to describe the nature of their symptoms (e.g., spinning, light-headedness or unsteadiness of feet) only if they had experienced any dizziness or imbalance. This illustrates the difficulty in comparing outcomes across studies [20].

In our study, most participants reported that dizziness and imbalance had no or an occasional effect on daily life and activities, while approximately about 5% frequent or constant effects. A study in the adult population of the city of São Paulo found that three in ten participants reported dizziness having some degree of disability (mild to severe) [20]. Additionally, the study found that medical help-seeking was directly related to the degree of discomfort, with nearly half (46%) of those with dizziness having consulted a doctor for their dizziness [20]. Given the high prevalence and potential impact of dizziness on daily life, it is an important health issue.

Dizziness places a significant burden not only on patients but also on the healthcare system. A recent retrospective analysis of medical expenses data, in a US nationally representative sample found that the mean incremental annual healthcare expenditure directly associated with vertigo or dizziness in adults was US$2,658.73 (95% CI: 1868.79, 3385.66) after controlling for socioeconomic and demographic characteristics [34]. Moreover, a systematic review of vestibular disease in primary health care revealed considerable variations in diagnostic criteria, referrals and therapies provided for patients with vertigo or dizziness [35]. Improving the delivery of care for these patients or preventing dizziness and its negative consequences of dizziness on daily life could be important to reduce the social and economic burden of the condition.

One of the noteworthy outcomes in our study, based on effect size, was that participants experiencing dizziness or imbalance symptoms more often reported having a history of ear problems or a hearing impairment. *Potential mechanisms underlying these findings* might be a situation of inner ear dysfunction or disorders affecting hearing as well as vestibular function. For example, we found that having Meniere's disease was strongly associated with experiencing dizziness or imbalance, with a reasonable large effect size (OR 7.55 (CI 4.10-13.91)). This is not surprising as these symptoms are part of the diagnostic criteria [36]. Previous studies have also found a higher prevalence of Meniere's disease and migraine in women [37, 38]. In our sample, women were more likely to report a spinning sensation or a feeling of movement related to their dizziness or imbalance—symptoms commonly associated with migraine or Meniere's disease. This finding may therefore be related to the higher prevalence of these diseases in women.

Regarding general health, participants with a history of cardiometabolic diseases or elevated cardiometabolic risks factors more often reported dizziness or imbalance compared to those without such conditions, consistent with findings from other studies [18, 21]. However, others have not confirmed this relationship [22]. From the current study it is hard to conclude on the underlying mechanisms of these findings; is it that cardiometabolic factors cause dizziness or imbalance of vice versa? Or do other, currently not known mechanisms play a role? While cardiometabolic factors are found to contribute to pathological and functional changes in inner ear structures [39, 40], dizziness may also result from postural hypotension, cardiac-related reduced blood pressure, or fluctuations in blood sugar as part of metabolic diseases. In the vice-versa relationship, symptoms of dizziness or imbalance could introduce a diminished ability for physical activity and, in turn, contribute to cardiometabolic health conditions. Longitudinal studies incorporating a variety of measures related to these conditions could contribute to a more detailed analysis of these cause-and-effect relationships and/or mediating factors. The inconsistencies so far found across studies on the association between dizziness or imbalance and cardiometabolic factors may not only be attributed to differences in the characteristics of the studied populations and settings, but also to variations in the way that potential associated factors were measured. For example, while a previous diagnosis of having diabetes was found to be associated with dizziness or imbalance symptoms, pre-diabetic and diabetic blood glucose at time of physical assessment were not. This can be explained by differences in disease stages or the effects of treatment. Future studies should conduct a more detailed analysis of these cardiometabolic factors in relation to dizziness, incorporating subjective and objective measures of cardiometabolic conditions and risks, while also considering the effect of health interventions such as medication or physical rehabilitation programs.

Lastly, our study found a strong association between dizziness or imbalance symptoms and higher mental health distress scores and disorders, which aligns with existing literature [5]. A recent systematic review even suggested an association between vestibular dysfunction and impaired cognitive function [41]. This could be explained by dizziness-related limitations on participation in social activities and reduced autonomy. But again, the explanation of these findings could be bidirectional in which higher mental distress and disorders could also introduce symptoms of dizziness or imbalance—for example, through stress-related hyperventilation, triggering migraine attacks, inducing autonomic nervous system dysregulation, or through medication side effects is possible. This warrants additional analysis to explore causality in detail before drawing conclusions.

Table 4 Outcomes of association between Dizziness or imbalance and its nature and general health

	imbalance or dizziness (*N* = 5086)			Outcomes of those with imbalance or dizziness by nature of symptoms (*N* = 1216)								
				Spinning/sensation of movement			Light-headedness			Unsteadiness on feet		
	Yes *N* (%)	OR (95%CI)	Adjusted OR (95%CI)	Yes *N* (%)	OR (95%CI)	Adjusted OR (95% CI)	Yes *N* (%)	OR (95% CI)	Adjusted OR (95%CI)	Yes *N* (%)	OR (95%CI)	Adjusted OR (95% CI)
Total (Missing *n* = 5)	1216 (23.8)			449 (36.9)			782 (64.3)			432 (35.5)		
Stroke												
No (ref)	1176 (96.7)	—	—	435 (96.9)	—	—	754 (96.4)	—	—	412 (95.4)	—	—
Yes (Missing *n* = 0)	40 (3.3)	**1.96 (1.31–2.90)**	**2.14 (1.43–3.21)**	14 (3.1)	0.92 (0.47–1.78)	1.08 (0.55–2.12)	28 (3.6)	1.31 (0.66–2.60)	1.41 (0.71–2.82)	20 (4.6)	1.85 (0.99–3.49)	1.70 (0.90–3.22)
PAD												
No (ref)	1187 (97.6)	—	—	438 (97.6)	—	—	765 (97.8)	—	—	417 (96.5)	—	—
Yes (Missing *n* = 0)	29 (2.4)	1.37 (0.88–2.12)	1.52 (0.97–2.38)	11 (2.4)	1.15 (0.49–2.23)	1.21 (0.56–2.61)	17 (2.2)	0.78 (0.37–1.65)	0.81 (0.38–1.71)	15 (3.5)	1.98 (0.95–4.14)	1.91 (0.91–4.02)
Heart disease												
No (ref)	1153 (94.8)	—	—	428 (95.3)	—	—	739 (94.5)	—	—	411 (95.1)	—	—
Yes (Missing *n* = 0)	63 (5.2)	**1.56 (1.14–2.11)**	**1.88 (1.37–2.59)**	21 (4.7)	0.85 (0.50–1.45)	1.10 (0.63–1.91)	43 (5.5)	1.20 (0.70–2.08)	1.38 (0.79–2.41)	21 (4.9)	0.90 (0.53–1.55)	0.75 (0.43–1.31)
Hypertension diagnosed or drugs BP												
No (ref)	693 (57.0)	—	—	254 (56.6)	—	—	447 (57.2)	—	—	213 (49.3)	—	—
Yes (Missing *n* = 0)	523 (43.0)	1.09 (0.95–1.24)	1.10 (0.96–1.27)	195 (43.3)	1.03 (0.81–1.30)	1.14 (0.89–1.47)	335 (42.8)	0.98 (0.77–1.24)	1.08 (0.84–1.38)	219 (50.7)	**1.62 (1.28–2.06)**	**1.49 (1.16–1.90)**
Blood pressure (AHA classification)												
Normal (ref)	346 (28.5)	—	—	120 (26.7)	—	—	238 (30.4)	—	—	105 (24.3)	—	—
Elevated	233 (19.2)	**0.81 (0.66–0.98)**	0.86 (0.71–1.05)	76 (16.9)	0.91 (0.64–1.30)	1.02 (0.71–1.46)	157 (20.1)	0.94 (0.66–1.34)	0.97 (0.68–1.39)	74 (17.1)	1.07 (0.75–1.53)	1.02 (0.71–1.47)
Hypertension stage 1	272 (22.4)	**0.64 (0.53–0.76)**	**0.72 (0.59–0.87)**	114 (25.4)	1.36 (0.98–1.89)	**1.61 (1.15–2.26)**	157 (20.1)	**0.62 (0.45–0.86)**	**0.65 (0.47–0.91)**	107 (24.8)	**1.49 (1.07–2.08)**	1.38 (0.98–1.94)
Hypertension stage 2 (Missing *n* = 0)	365 (30.0)	**0.76 (0.64–0.90)**	**0.81 (0.68–0.97)**	139 (31.0)	1.16 (0.85–1.57)	1.34 (0.97–1.85)	230 (29.4)	0.77 (0.57–1.06)	0.84 (0.61–1.16)	146 (33.8)	**1.53 (1.12–2.09)**	1.36 (0.99–1.88)
DM diagnosed												
No (ref)	1119 (92)	—	—	416 (92.7)	—	—	720 (92.1)	—	—	386 (89.4)	—	—
Yes (Missing *n* = 0)	97 (8.0)	**1.34 (1.04–1.71)**	**1.35 (1.05–1.74)**	33 (7.3)	0.87 (0.65–1.35)	0.93 (0.60–1.45)	62 (7.9)	0.98 (0.64–1.51)	1.04 (0.67–1.61)	46 (10.6)	**1.71 (1.30–2.60)**	**1.59 (1.05–2.43)**
(pre)DM ADA classification												
No (ref)	595 (48.9)	—	—	227 (50.6)	—	—	375 (48.0)	—	—	204 (47.2)	—	—
Pre-DM	550 (45.2)	1.03 (0.90–1.18)	1.04 (0.91–1.19)	198 (44.1)	0.91 (0.72–1.16)	0.93 (0.73–1.19)	362 (46.3)	1.13 (0.89–1.44)	1.16 (0.91–1.48)	199 (46.1)	1.09 (0.85–1.39)	1.06 (0.83–1.35)

Table 4 (continued)

	imbalance or dizziness (*N* = 5086)			Outcomes of those with imbalance or dizziness by nature of symptoms (*N* = 1216)								
				Spinning/sensation of movement			Light-headedness			Unsteadiness on feet		
	Yes *N* (%)	OR (95%CI)	Adjusted OR (95%CI)	Yes *N* (%)	OR (95%CI)	Adjusted OR (95% CI)	Yes *N* (%)	OR (95% CI)	Adjusted OR (95%CI)	Yes *N* (%)	OR (95%CI)	Adjusted OR (95% CI)
DM (Missing *n* = 0)	71 (5.8)	1.21 (0.90–1.60)	1.31 (0.98–1.76)	24 (5.3)	0.83 (0.49–1.39)	0.92 (0.54–1.56)	45 (5.8)	1.02 (0.61–1.69)	1.08 (0.65–1.81)	29 (6.7)	1.32 (0.80-21.19)	1.22 (0.74–2.03)
BMI[#] (Missing *n* = 0)	28.6 (5.5)	**1.02 (1.01–1.03)**	**1.02 (1.01–1.04)**	28.7 (5.6)	1.01 (0.99–1.03)	1.01 (0.99–1.03)	28.4 (5.3)	0.99 (0.97–1.01)	0.99 (0.97–1.01)	29.7 (6.0)	**1.06 (1.04–1.08)**	**1.06 (1.03–1.08)**
Thyroid disease												
No (ref)	1066 (87.7)	—	—	394 (87.8)	—	—	684 (87.5)	—	—	368 (85.2)	—	—
Yes (Missing *n* = 0)	150 (12. 3)	**1.71 (1.39–2.10)**	**1.36 (1.10–1.70)**	55 (12.2)	0.99 (0.69–1.41)	0.88 (0.61–1.26)	98 (12.5)	1.05 (0.74–1.51)	1.07 (0.74–1.54)	64 (14.8)	1.41 (1.00–2.00)	1.40 (0.98–2.01)
SF12 PCS[#] (Missing *n* = 0)	46.6 (10.9)	**0.95 (0.95–0.96)**	**0.95 (0.95–0.96)**	46.7 (11.3)	1.00 (0.99–1.01)	1.00 (0.99–1.01)	46.8 (10.6)	1.01 (1.00-1.02)	1.00 (0.99–1.02)	43.5 (12.1)	**0.96 (0.95–0.97)**	**0.96 (0.95–0.97)**
Chronic ear infection												
No (ref)	1090 (89.8)	—	—	401 (89.3)	—	—	694 (89.0)	—	—	384 (88.9)	—	—
Yes (Missing *n* = 2)	124 (10.2)	**1.98 (1.57–2.50)**	**1.93 (1.52–2.44)**	48 (10.7)	1.09 (0.74–1.59)	1.01 (0.69–1.49)	86 (11.0)	1.29 (0.87–1.93)	1.25 (0.83–1.86)	48 (11.1)	1.16 (0.79–1.70)	1.23 (0.84–1.81)
Meniere's disease												
No (ref)	1177 (97.0)	—	—	423 (94.4)	—	—	756 (96.8)	—	—	415 (96.1)	—	—
Yes (Missing *n* = 2)	37 (3.0)	**8.07 (4.41–14.75)**	**7.55 (4.10-13.91)**	25 (5.6)	**3.71 (1.85–7.47)**	**3.94 (1.94–7.99)**	25 (3.2)	1.16 (0.58–2.33)	0.23 (0.61–2.48)	17 (3.9)	1.56 (0.81–3.01)	1.44 (0.75–2.80)
Migraine												
No (ref)	906 (74.6)	—	—	320 (71.4)	—	—	581 (74.5)	—	—	302 (70.1)	—	—
Yes (Missing *n* = 2)	308 (25.4)	**1.91 (1.63–2.23)**	**1.67 (1.42–1.96)**	128 (28.6)	1.30 (1.00-1.70)	1.19 (0.91–1.56)	199 (25.5)	1.02 (0.78–1.34)	1.00 (0.76–1.32)	129 (29.9)	**1.44 (1.11–1.88)**	**1.51 (1.15–1.97)**
Hearing impairment												
No (ref)	906 (74.8)	—	—	347 (77.3)	—	—	586 (75.1)	—	—	291 (67.5)	—	—
Yes (Missing *n* = 4)	306 (25.2)	**2.04 (1.54–2.69)**	**2.50 (1.88–3.34)**	102 (22.7)	0.97 (0.62–1.54)	0.95 (0.71–1.26)	194 (24.9)	**0.57 (0.37–0.89)**	1.01 (0.77–1.34)	140 (32.5)	**2.16 (1.39–3.36)**	**1.70 (1.29–2.23)**

Outcomes of univariate analysis of the association between experienced dizziness or imbalance and its nature in relation to general health characteristics. Values reported in n (%) or mean (SD) when indicated by [#]; CI = Confidence Interval, N = number, NA = not applicable by too low cases in the equation, OR = Odds Ratio, ref = reference category. Significant outcomes with p-values ($p < 0.05$) are depicted bold

Table 5 Outcomes of association between Dizziness or imbalance and its nature and mental health

	imbalance or dizziness (*N* = 5086)			Outcomes of those with imbalance or dizziness by nature of symptoms (*N* = 1216)								
				Spinning/sensation of movement			Light-headedness			Unsteadiness on feet		
	Yes N (%)	OR (95%CI)	Adjusted OR (95%CI)	Yes N (%)	OR (95%CI)	Adjusted OR (95% CI)	Yes N (%)	OR (95% CI)	Adjusted OR (95%CI)	Yes N (%)	OR (95%CI)	Adjusted OR (95% CI)
Total (Missing *n* = 5)	1216 (23.8)			449 (36.9)			782 (64.3)			432 (35.5)		
Depression diagnosed												
No (ref)	767 (63.1)	—	—	263 (58.6)	—	—	491 (62.8)	—	—	234 (54.2)	—	—
Yes (Missing *n* = 0)	449 (36.9)	**1.91 (1.66–2.19)**	**1.76 (1.53–2.03)**	186 (41.4)	**1.36 (1.07–1.72)**	**1.31 (1.03–1.67)**	291 (37.2)	1.04 (0.81–1.32)	1.04 (0.81–1.32)	198 (45.8)	**1.80 (1.41–2.29)**	**1.81 (1.42–2.31)**
PHQ9 depressive disorder												
None (ref)	1107 (91.0)	—	—	404 (90.0)	—	—	708 (90.5)	—	—	380 (88.0)	-—	—
Other	46 (3.8)	**2.39 (1.63–3.51)**	**2.45 (1.66–3.62)**	15 (3.3)	1.72 (0.99-3.00)	0.90 (0.48–1.70)	29 (3.7)	**2.08 (1.35–3.22)**	0.98 (0.53–1.81)	21 (4.9)	**2.76 (1.69–4.50)**	1.58 (0.87–2.86)
Major (Missing *n* = 0)	63 (5.2)	**3.55 (2.48–5.09)**	**3.51 (2.43–5.05)**	30 (6.7)	**3.72 (2.44–5.68)**	1.51 (0.90–2.52)	45 (5.8)	**3.41 (2.33–4.98)**	1.36 (0.78–2.39)	31 (7.2)	**3.98 (2.61–6.07)**	**1.97 (1.18–3.29)**
DASS Depression[#]	5.44 (7.25)	**1.05 (1.04–1.06)**	**1.06 (1.04–1.07)**	5.88 (7.91)	**1.05 (1.04–1.06)**	1.01 (0.99–1.03)	5.42 (7.26)	**1.05 (1.03–1.06)**	1.00 (0.98–1.01)	6.67 (8.20)	**1.06 (1.05–1.08)**	**1.04 (1.02–1.06)**
Normal	784 (64.5)			287 (63.9)			504 (64.5)			256 (59.3)		
Mild	99 (8.1)			39 (8.7)			66 (8.4)			32 (7.4)		
Moderate	119 (9.8) 52			39 (8.7)			77 (9.8)			48 (11.1)		
Severe	(4.3)			16 (3.6)			33 (4.2)			20 (4.6)		
Extremely severe	162 (13.3)			68 (15.1)			102 (13.0)			76 (17.6)		
(Missing *n* = 0)												
DASS Anxiety[#]	4.15 (5.46)	**1.12 (1.10–1.13)**	**1.11 (1.10–1.13)**	4.53 (5.94)	**1.10 (1.07–1.11)**	1.02 (0.99–1.04)	4.27 (5.53)	**1.10 (1.08–1.12)**	1.01 (0.99–1.03)	5.19 (6.51)	**1.12 (1.10–1.11)**	**1.06 (1.03–1.08)**
Normal	703 (57.8)			248 (55.2)			441 (56.4)			227 (52.5)		
Mild	176 (14.5)			67 (14.9)			112 (14.3)			59 (13.7)		
Moderate	100 (8.2)			35 (7.8)			79 (10.1)			38 (8.8)		
Severe	68 (5.6)			30 (6.7)			41 (5.2)			28 (6.5)		
Extremely severe	169 (13.9)			69 (15.4)			109 (13.9)			80 (18.5)		
(Missing *n* = 0)												

Table 5 (continued)

	imbalance or dizziness ($N=5086$)			Outcomes of those with imbalance or dizziness by nature of symptoms ($N=1216$)								
DASS Stress[#]	8.37 (7.61)	**1.06 (1.05–1.06)**	**1.06 (1.05–1.07)**	8.76 (8.10)	**1.05 (1.04–1.06)**	1.01 (0.99–1.03)	8.66 (7.65)	**1.05 (1.04–1.07)**	1.01 (1.00-1.03)	9.62 (8.18)	**1.07 (1.05–1.08)**	**1.04 (1.02–1.05)**
Normal	609 (50.1)			219 (48.8)			366 (46.8)			193 (44.7)		
Mild	123 (10.1)			49 (10.9)			83 (10.6)			37 (8.6)		
Moderate	202 (16.6)			70 (15.6)			151 (19.3)			79 (18.3)		
Severe	132 (10.9)			49 (10.9)			86 (11.0)			51 (11.8)		
Extremely severe	150 (12.3)			62 (13.8)			96 (12.3)			72 (16.7)		
(Missing $n=0$)												
SF12 MCS[#] (Missing $n=0$)	50.9 (9.6)	**0.96 (0.96–0.97)**	**0.96 (0.96–0.97)**	50.4 (10.4)	0.99 (0.98-1.00)	0.99 (0.98–1.01)	50.6 (9.4)	0.99 (0.98-1.00)	0.99 (0.98–1.01)	50.2 (10.2)	0.99 (0.98-1.00)	**0.99 (0.973–0.997)**

Outcomes of univariate analysis of the association between experienced dizziness or imbalance and its nature in relation to mental health characteristics. Values reported in numbers (N) (%) or mean (SD) when indicated by [#]; OR = Odds Ratio, CI = Confidence Interval, ref = reference category. NA; not applicable by too low cases in the equation. Significant outcomes with p-values ($p<0.05$) are depicted bold

With the availability of a rich dataset on dizziness or imbalance, including hearing loss, one might suggest that questionnaire data can be used to classify people into groups of etiology of their dizziness or imbalance, allowing for a more detailed study of prevalence and associations. For example, in Kentala et al.'s study, patients with 'true vertigo' (defined as a false sense of motion) were classified into Benign Paroxysmal Positional Vertigo (BPPV), Meniere's disease, labyrinthitis or neuritis like group based on the temporal pattern and accompanying hearing loss [42]. However, this method could not be replicated in our study due to the differences between studies in questions to describe symptoms. Additionally, relying on questionnaires to categorize dizziness and imbalance in groups of etiological groups presented challenges, particularly because correctly recalling or identifying specific (temporal) patterns of symptoms can be difficult for participants [43]. In current practice diagnosing dizziness disorders typically involves a combination of symptoms, clinical examination and physical tests. Moreover, current diagnostic criteria for several dizziness disorders, such as Meniere's disease [36] or hemodynamic orthostatic dizziness [44] allow for a probable diagnosis even in cases with a less obvious pattern of symptoms, making it challenging to establish clear and reliable boundaries between disorders.

To facilitate a more detailed assessment of prevalence and associated factors related to vestibular and non-vestibular disorders, future studies will need to incorporate outcomes of physical examination and testing. This highlights the need for consensus on the use of a valid and reliable vestibular test battery for populational study settings.

Several other methodological issues should be noted. The strength of this study is that we were able to present findings on the prevalence and impact of dizziness and imbalance on daily life and activities in a large and diverse sample of adults aged 45 to 70 years from the general population. Using cross-sectional data, we conducted an exploratory analysis of demographics, physical health, and mental health associated with dizziness and imbalance. However, we deliberately refrained from developing prediction models for these symptoms of dizziness and imbalance or analyzing exposure-effect relationships with explanatory models [45]. Future research should focus on investigating causal interference in large population samples with detailed health data, as this could be crucial for enhancing our understanding of the occurrence of dizziness and imbalance symptoms. Statistical models can be employed to analyze causality or explore specific causal relationships between factors based on predefined hypothesis. For such analyses, a sufficient set of confounders must be identified from external knowledge of causality, measured accurately in

the study and included in the analytic model to minimise residual confounding and prevent incorrect causal inferences [45]. The current work serves as a starting point for generating hypotheses and guiding future studies.

Second, in our study population, the younger age groups and males were underrepresented compared to the population estimates of the city of Busselton. To improve generalizability, we adjusted for age and sex in the analyses of associations. However, descriptive findings, such as the frequency and duration of symptoms or impact on daily life, still reflect the characteristics of the selected sample and may not be representative of the population of Busselton. Furthermore, these adjustments do not guarantee the generalizability of outcomes to other populations, as each population will be characterized by specific population proportions on age, sex and many other (non)demographic variables.

Thirdly, the phrasing of the index question ('*Do you experience any imbalance or dizziness*') without further subdivision of complaints, did not allow for a distinguishment between those participants experiencing imbalance from those experiencing only dizziness. Future studies should guide the participants to distinguish between dizziness and imbalance.

Finally, the effect of dizziness or imbalance problems on daily life was assessed with a single-item question rather than a validated multi-item questionnaire, such as the Dizziness Handicap Inventory. The use of a single item limited direct comparisons with other studies on the effect of dizziness and imbalance symptoms.

Conclusions

In this study, we demonstrated that dizziness and imbalance are common symptoms among individuals aged 45 to 70 years, with light-headedness the most frequently reported sensation. Given the high prevalence and the potential influence of these symptoms on daily life in middle-aged people, this information is essential for general healthcare practitioners. Actively assessing symptoms of dizziness and imbalance in the adult population could be incorporated into routine medical assessments in clinical practice.

Recognizing dizziness or imbalance complaints, along with their associations could serve as a starting point of counselling of patients on maintaining autonomy and social participation, thereby promoting healthy ageing [46]. Additionally, knowledge of the prevalence of and associations with dizziness and imbalance are important for guiding health-care policymakers in designing rehabilitation programs and direct societal healthcare planning.

Abbreviations

ABI	Ankle Brachial Index
ADA	American Diabetes Association
AHA	American Heart Association
AUD	Australian dollar
BMI	Body mass index
BPPV	Benign paroxysmal positional vertigo
CI	Confidence Interval
DM	Diabetes mellitus
FPG	Fasting Plasma Glucose
HbA1c	Glycated haemoglobin
MAP	Mean arterial pressure
OR	Odds ratio
PAD	Peripheral artery disease
SD	Standard deviation
TIA	Transient Ischemic Attack

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Author contributions

ALS, IS and RE analyzed and interpreted the data and were the major contributors in writing the manuscript. RSB, MDA and MH were involved in the study design and data collection, critically assessed the findings of the study and provided feedback on the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Study data were taken from the Busselton Healthy Ageing Study (BHAS) [26]. This study was conducted according to the Declaration of Helsinki and was approved by The University of Western Australia Human Research Ethics Committee (Number RA/4/1/2203). All participants gave their informed written consent before inclusion in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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