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Original article

Low bone mineral density is associated with balance and hearing impairments

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ABSTRACT

Purpose: Bone demineralization affects the skeletal system, including the temporal bone, which contains the cochlea and the vestibular labyrinth. However, research on the association of bone mineral density (BMD) with balance and hearing sensitivity is limited with conflicting results. Therefore, we examined the relationship in a population representative sample.

Methods: We analyzed 8863 participants to the National Health and Nutrition Examination Survey (1999–2004) aged 40 years and older. Total and head BMD were measured by dual energy x-ray absorptiometry. Balance was evaluated using the Romberg Test of Standing Balance on Firm and Compliant Support Surfaces condition 4, also indicative of vestibular dysfunction. Hearing condition was self-reported. The associations of total and head BMD with balance and hearing were assessed using multiple and multinomial logistic regressions adjusting for covariates.

Results: On multiple logistic regression, low total BMD was associated with balance impairment (odds ratio [OR], 2.21; 95% confidence interval [CI], 1.43–4.75), especially in older adults (≥65 years old; OR, 3.72; 95% CI, 1.07–12.85). In multinomial regression, low total BMD was associated with report of significant hearing impairment in older adults (OR, 5.30; 95% CI, 1.20–23.26).

Conclusions: Low BMD is associated with balance and hearing impairments, especially in older adults.

Osteoporosis, defined as reduced bone mineral density (BMD) and bone tissue deterioration, is a major public health concern affecting 75 million people in the United States, Europe, and Japan and causing 8.9 million fractures per year worldwide [1]. Its prevalence and incidence are expected to rise with the rapid growth of the aging population. People with low BMD are particularly vulnerable to fractures because of fragile bones, especially when they have poor balance increasing their risk of falling [2–4]. Balance is controlled by a complex interaction between the visual, proprioceptive, and vestibular systems, which provide the central nervous system with information on the position of body allowing for postural control and balance maintenance [5]. Loss of balance and inability to recover from disturbances usually occur when the information sent from the sensory systems is unpredictable, insufficient, or conflicting [6].

Bone demineralization affects the skeletal system, including the temporal bone, which contains the vestibular labyrinth and the cochlea and thus could impact the vestibular and hearing functions [7]. Several reports have examined the consequences of falls in people with low BMD, but only a few small sample-sized studies of women, investigated the relationship between low BMD and balance, yielding conflicting results [3,7–9]. Likewise, studies on BMD and hearing sensitivity have also reported complicated relationships. Hearing loss has been found associated with low femoral neck BMD, but not with low radial BMD in rural White women [8]. Another study found no association between hearing and BMD in Whites and in Black women, but hearing loss was associated with lower hip BMD in Black men [9]. A larger study of 1830 Korean postmenopausal women found no relationship between BMD and hearing [10].

The inconsistencies and limitations of previous studies suggest a need for additional research. Therefore, the objective of this study was to examine the relationship of low total and head BMD with postural balance and hearing impairments, using a large sample representative of the U.S. population.

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Materials and methods

Data source and study design

The source of data was the 1999 through 2004 National Health and Nutrition Examination Survey (NHANES), an ongoing cross-sectional survey of the civilian, noninstitutionalized U.S. population. The NHANES is conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention and collects data on demographics, health, and nutritional status of selected participants using a complex, multistage sampling design [11]. This study included all participants for whom information on BMD, balance testing, hearing status, and relevant covariates were available. Balance testing and information on hearing condition was available for 9970 adults aged 40 years and older who took part to the NHANES between 1999 and 2004. Among them, 8863 subjects had BMD measures taken and were included in our analysis (Fig. 1). The NHANES protocols were approved by the institutional review boards of the NCHS and Centers for Disease Control and Prevention and informed consent was obtained from all participants.

Balance and hearing condition assessment

Balance was evaluated using the Romberg Test of Standing Balance on Firm and Compliant Support Surfaces (RTSBFCSS), which tests the ability to stand unassisted under four conditions of increasing difficulty. In condition one, the subject stands using the vestibular system, vision, and proprioception to maintain balance (standard standing without visual-sensory restriction). In condition two, the subject closes his/her eyes; the visual input is removed, leaving only vestibular and proprioceptive cues to maintain balance. Condition three uses a foam surface to reduce the proprioception and tests vestibular and visual inputs. Condition four exclusively tests the vestibular system using a foam pad and requiring the subject's eyes to be closed. Participants were classified as having balance problems and possibly vestibular dysfunction if they failed test condition four. Failure was defined as the need to open eyes, move arms or feet to achieve stability, begin to fall, or require intervention to maintain balance. Participants who initially failed were allowed to retest once. Subjects were excluded from testing if they felt unable to stand on their own, had dizziness causing unsteadiness, weighed over 275 pounds, needed a leg brace to stand unassisted, had feet or legs amputation, were visually impaired, or had a waist circumference that could not accommodate the fitting of the safety gait belt. Additionally, participants with kyphosis or vertebral fracture ($n = 152$) were excluded.

Hearing was evaluated by asking the participants about their hearing status. They were classified as having no hearing trouble (0), little hearing trouble (1), or significant hearing trouble (much hearing trouble or deafness; 2).

BMD

Total and head BMD was measured using dual energy x-ray absorptiometry taken with a Hologic QDR-4500 A fan-beam densitometer (Hologic, Inc., Bedford, MA). Participants, positioned supine on the tabletop with their feet in a neutral position and hands flat by their side, were scanned with an x-ray source using fan-beam scan geometry in three 1-minute passes. Examinations were completed by certified radiology technologists and the scans were analyzed in the Department of Radiology of the University of California-San Francisco. The five 1999 through 2004 NHANES DXA multiple imputation data files released by the NCHS were used as described (available at http://www.cdc.gov/nchs/data/nhanes/dxa/dxa_techdoc.pdf).

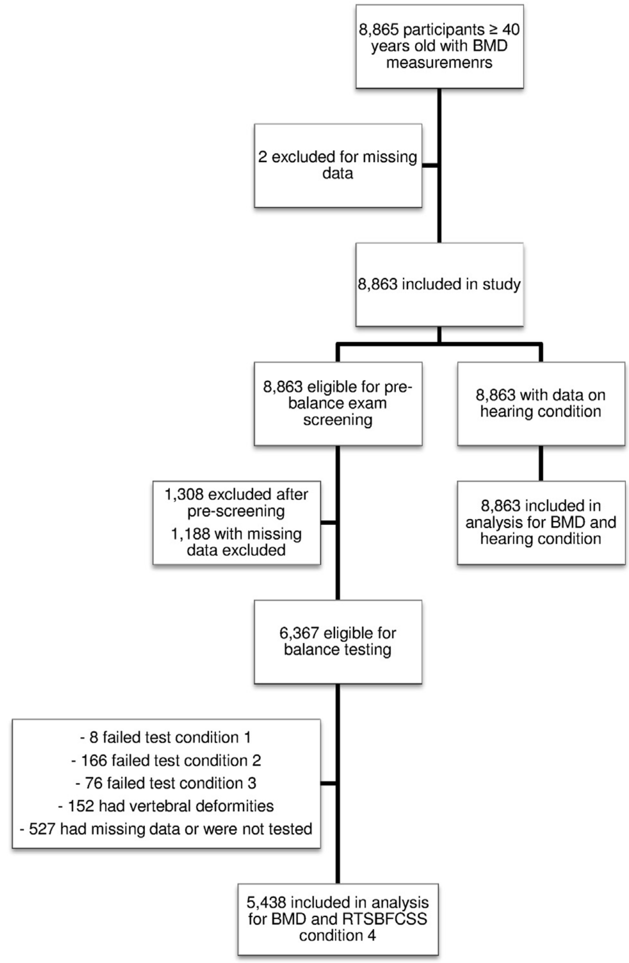

Fig. 1. Flow chart for number of participants.

Other variables

Information on demographic characteristics (age, gender, race/ethnicity, household income, and education level), alcohol consumption, medications used in past 30 days and medical conditions were obtained from the NHANES questionnaire. Physical activity was evaluated by questions related to work or leisure time physical activities and metabolic equivalent task scores were calculated. Medical conditions were defined as having answered "yes" or "no" to questions regarding: diabetes (e.g., "has a doctor or other health professional ever told you that you have diabetes?"), high blood pressure, arthritis, stroke, confusion/memory problem, trouble seeing even with glasses or lenses, coronary heart disease, congestive heart failure, angina pectoris, heart attack, cancer, joint pain, and migraines/headaches.

Participants' weight and height were measured in a mobile examination center using standardized techniques and equipment. Body mass index was calculated as weight in kilograms divided by height in squared meters. Exposure to cigarette smoke was determined by measuring serum cotinine levels using isotope dilution, high-performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry [12]. Serum total cholesterol was enzymatically measured in serum using the Roche Hitachi 717 and 912. Serum vitamin B_{12} was measured with the Bio-Rad Laboratories (Hercules, CA) "Quantaphase II Folate/Vitamin B_{12}" radioassay kit. The Beckman Coulter MAXM instrument (Beckmas Coulter, Fullerton, CA), a quantitative automated