Bone 56 (2013) 320–326

Contents lists available at ScienceDirect

Bone

journal homepage: www.elsevier.com/locate/bone

Original Full Length Article

Childhood socioeconomic status and adult femoral neck bone strength: Findings from the Midlife in the United States Study

Arun S. Karlamangla [a,*], Takahiro Mori [b], Sharon S. Merkin [a], Teresa E. Seeman [a], Gail A. Greendale [a], Neil Binkley [c], Carolyn J. Crandall [d]

[a] Division of Geriatrics, Department of Medicine, David Geffen School of Medicine at UCLA, 10945 Le Conte Ave., Suite 2339, Los Angeles, CA 90095, USA
[b] Geriatric Research Education and Clinical Center, VA Greater Los Angeles Healthcare System, 11301 Wilshire Blvd., Los Angeles, CA 90073, USA
[c] University of Wisconsin–Madison Osteoporosis Clinical Center and Research Program, School of Medicine and Public Health, 2245 MSC, 1300 University Avenue, Madison, WI 53706, USA
[d] Division of General Internal Medicine and Health Services Research, David Geffen School of Medicine at UCLA, 911 Broxton Ave., Los Angeles, CA 90095, USA

ARTICLE INFO

Article history:
Received 30 November 2012
Revised 16 May 2013
Accepted 18 June 2013
Available online 28 June 2013

Edited by: Felicia Cosman

Keywords:
Bone strength
Femoral neck
Childhood socioeconomic advantage
Health behaviors

ABSTRACT

Purpose: Bone acquisition in childhood impacts adult bone mass, and can be influenced by childhood socioeconomic conditions. Socioeconomic status is also associated with body weight which affects the load that bone is exposed to in a fall. We hypothesized that socioeconomic advantage in childhood is associated with greater bone strength relative to load in adulthood.

Methods: Hip dual x-ray absorptiometry scans from 722 participants in the Midlife in the United States Study were used to measure femoral neck size and bone mineral density, and combined with body weight and height to create composite indices of femoral neck strength relative to load in different failure modes: compression, bending, and impact. A childhood socioeconomic advantage score was created for the same participants from parental education, self-rated financial status relative to others, and not being on welfare. Multiple linear regression was used to determine the association of childhood socioeconomic advantage with femoral neck composite strength indices, stratified by gender and race (white/non-white), and adjusted for study site, age, menopause status in women, education, and current financial advantage.

Results: Childhood socioeconomic advantage was independently associated with higher indices of all three composite strength indices in white men (adjusted standardized effect sizes, 0.19 to 0.27, all p values < 0.01), but not in the other three race/gender groups. Additional adjustment for adult obesity, physical activity in different life stages, smoking, and heavy drinking over the life-course significantly attenuated the associations in white men.

Conclusions: Socioeconomic disadvantage in childhood is associated with lower hip strength relative to load in white men, and these influences are dampened by healthy lifestyle choices.

Introduction

Low socioeconomic status (SES), which has strong, well-documented associations with a variety of adverse health outcomes, is also associated with increased risk for hip fracture in older ages [1–6]. Hip fractures are a major cause of morbidity, physical disability, and even early mortality [6], and its economic impact is projected to increase worldwide in the coming decades [7,8]. It is therefore becoming increasingly important to delineate the mechanisms underlying the association between low SES and greater hip fracture risk, in order to allow the design and targeting of preventive interventions.

The major predictor of greater hip fracture risk is low bone mineral density (BMD) in the femoral neck; yet, studies have not found strong associations between low SES and low femoral neck BMD [9–13]. Of the various indicators of adult SES, education level more than income, occupation, or wealth, has shown consistent associations with BMD [14–18]. Because adult bone mass is a function of both acquisition in younger ages and decline in later life [19,20], and because educational attainment is generally completed by young adulthood, this suggests that social circumstances in the early years may be more relevant to bone health than circumstances in later life. In fact two recent studies have documented strong positive associations between childhood social advantage and adult BMD [18,21].

However, both childhood socioeconomic advantage and adult education are associated only with BMD in the lumbar spine and not with BMD in the femoral neck [14,16,18], the more important determinant of hip fracture risk [22–24]. Femoral neck BMD, though important, is not the only driver of femoral neck bone strength, and thus of hip fracture risk. The size of the femoral neck size also contributes to its structural strength [24–26] (just as the strength of engineering structures depends on both material density and structure

---

* Corresponding author at: Division of Geriatrics, Department of Medicine, David Geffen School of Medicine at UCLA, 10945 Le Conte Ave., Suite 2339, Los Angeles, CA 90095, USA. Fax: +1 310 794 2199.
E-mail address: akarlamangla@mednet.ucla.edu (A.S. Karlamangla).

8756-3282/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.bone.2013.06.021

size), while body size determines the fracture forces that the hip is exposed to in a fall [27]. It is not enough for BMD to be high to reduce fracture risk; the composite of BMD and bone size must be adequately high relative to fracture forces to keep the risk of fracture low. Thus, composite indices [28] that integrate femoral neck BMD, femoral neck size, and body size, to quantify the strength of the femoral neck relative to load [29–33], are inversely associated with incident hip fracture risk [28,34,35]. Unlike BMD, which fails to correctly stratify fracture risk across ethnic groups [36–39], femoral neck composite strength indices do correctly stratify risk across ethnic groups [40], and predict fracture risk in a middle-aged woman without requiring knowledge of her race/ethnicity [41]. Furthermore, unlike BMD which is higher in diabetes [42] and thus inconsistent with the increased hip fracture risk in diabetes [43], femoral neck composite strength indices are indeed lower in diabetics than in non-diabetics [44]. Thus, the femoral neck composite strength indices might be better measures of the individual's ability to resist hip fracture than is femoral neck BMD.

We postulate that the increased hip fracture risk in low SES groups is, at least partly, the result of inadequate bone acquisition in the femoral neck in childhood, and hypothesize that even if socioeconomic disadvantage in childhood is not associated with lower femoral neck BMD in adulthood, it will be associated with smaller indices of adult femoral neck strength relative to load. We used data from a national study to test this hypothesis.

Methods

The Study of Midlife in the United States (MIDUS), initiated in 1995, was designed to determine how social, psychological, and behavioral factors over the life course interact to influence health. The first wave of MIDUS collected demographic and psychosocial data on a national sample of English-speaking, non-institutionalized adults between 25 and 75 years of age residing in the coterminous United States whose household included at least one telephone (recruited by random digit dialing), and oversampled twin pairs and siblings [45]. In the second wave of data collection, 9–10 years later (MIDUS II), the sample was refreshed with African American residents recruited from Milwaukee, WI, specifically to increase the representation of urban African Americans. Details of sampling and recruitment are available online at http://www.icpsr.umich.edu/icpsrweb/NACDA/.

Of the 3191 MIDUS II participants deemed medically able to travel, 1255 participated between July 2004 and May 2009 in the MIDUS II Biomarker Project, which required a 2-day commitment, including travel to one of the three clinical research centers (University of California at Los Angeles, Georgetown University, and University of Wisconsin). Reasons given for nonparticipation were travel, family, and work obligations. MIDUS II Biomarker Project participants were similar to the MIDUS II sample with respect to key characteristics (e.g., subjective health, chronic conditions, physical activity, alcohol use) [46], and the complete MIDUS II sample was similar to the MIDUS I sample [47]. As part of the Biomarker Project, BMD was measured in the lumbar spine and the left femoral neck using dual-energy x-ray absorptiometry (DXA). Funding for DXA scanning at two of the three sites (UCLA and Georgetown) was obtained after the Biomarker Project had commenced; thus, DXA scans were not available for every participant at these sites. Informed consent was provided by each participant, and each MIDUS center obtained institutional review board approval [46].

Of the 1255 participants in the MIDUS II Biomarker Project, we excluded data from 348 participants who did not have measureable DXA scans (and thus, femoral neck strength measurement), an additional 94 participants who reported the use of medications known to influence BMD (i.e., oral corticosteroids, alendronate, anastrozole, calcitonin, ibandronate, leuprolide, letrozole, raloxifene, risedronate, tamoxifen, zoledronic acid, testosterone, finasteride, dutasteride), another 88 women whose menopause transition stage could not be determined, and 3 participants for whom we lacked complete childhood SES information. Thus, the analytic sample for this study was comprised of 722 participants, 349 men and 373 women. An additional 10 participants were missing adult SES information and were excluded in analyses that included controls for adult SES.

Femoral neck strength measurement

As part of the MIDUS Biomarker Project, DXA scans were performed with standardized protocols, using GE Healthcare Lunar Prodigy (U. Wisconsin–Madison) or Hologic 4500 (UCLA and Georgetown U.) machines, by technologists certified by the International Society for Clinical Densitometry. Three times per week, and on all days on which scans were obtained, instruments were calibrated. No densitometer shift or drift occurred during the course of this study. Adjudication of all DXA scans occurred centrally at the University of Wisconsin DXA center, using software provided by the manufacturers (Lunar, Inc., and Hologic, Inc.), and included measurement of the 2D projected areal BMD in the femoral neck, the femoral neck axis length (FNAL) – the distance on the 2D projected plane along the femoral neck axis from the lateral margin of the base of the greater trochanter to the apex of the femoral head, and the femoral neck width (FNW) – the smallest thickness of the femoral neck on the 2D projected plane along a line perpendicular to the femoral neck axis (Fig. 1). Composite indices of femoral neck strength, that index bone strength relative to the load during a fall, were calculated from these DXA-based measurements and body height and weight, using the following formulas [28], which have been validated against 3D methods based on quantitative computed tomography [48].

$$\text{Compression Strength Index (CSI)} = \frac{\text{BMD} * \text{FNW}}{\text{Weight}}$$

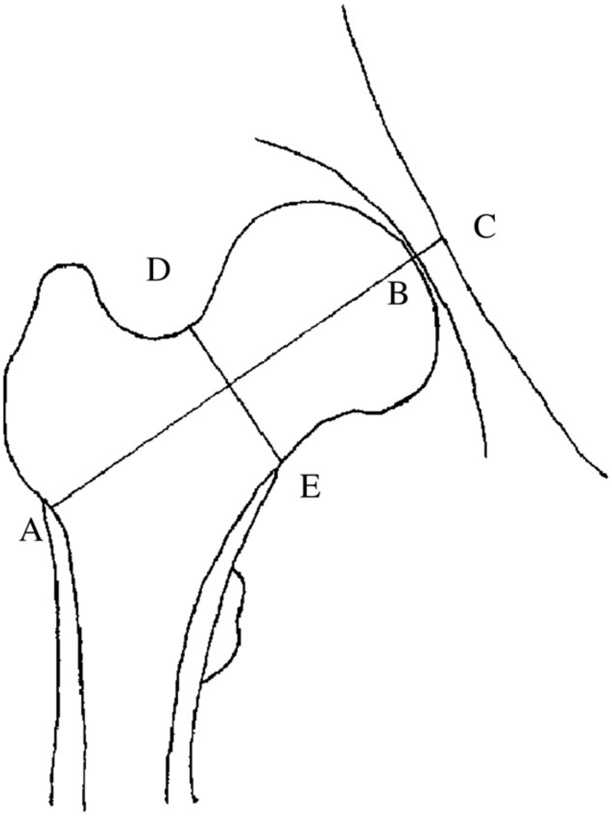

Fig. 1. Geometry of the femoral neck: AB is the femoral neck axis length and DE is the femoral neck width.