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ORIGINAL ARTICLE

Bone Tissue in Down Syndrome Patients Deteriorates Following Aging: A Study Based on Bone Ultrasound Analysis

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Background: Osteoporosis represents one of the main factors contributing to premature morbidity in individuals with Down syndrome (DS) characterized by muscle hypotonia. The purpose of this study was to assess the bone ultrasound properties in a cohort of patients with DS with reference to age and body tonicity.
Materials and methods: One hundred and ninety-three patients with DS and 246 healthy individuals participated in this study. Broadband ultrasound attenuation (BUA) and speed of sound values were measured by an Achilles Lunar Insight device. Stabilometric performances were obtained from a force platform. The participants were divided into four age groups (with mean ages 10.8 years, 15.2 years, 20.5 years, and 33.4 years) using a decision tree procedure.
Results: Patients with DS displayed lower BUA than controls at the two older age groups. Stabilometric performances expressed by patients with DS were independent of age, whereas those displayed by the controls showed an improvement in stability and tonicity with age. All these performances were significantly higher in controls. BUA presented a negative correlation with stabilometric values ($p < 0.05$), except for area ($p = 0.103$).
Conclusion: This study showed that BUA is sufficiently sensitive to highlight the bone degradation that occurs at the end of adolescence and in adulthood in individuals with DS. In addition,

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BUA and stabilometric performances were able to distinguish DS patients from controls in the two older age groups, indicating that bone tissue and postural control of DS patients deteriorate with aging.

Introduction

Down syndrome (DS), the most common genetic cause of developmental disability, is characterized by intellectual impairment and musculoskeletal disorders [1]. Clinically, children with DS are described as having low tone, or low stiffness, which may affect muscle strength and motor skills [2]. Recently, osteoporosis has been identified in individuals with DS, being one of the main factors contributing to both premature morbidity and mortality in this population [3]. The significant increase in life expectancy of this population may explain the onset of osteoporosis. Indeed, life expectancy of DS patients was less than 50 years two decades ago. Currently, patients with DS may reach 65 years of age on average and, therefore, can be affected by this disease. In addition, thyroid dysfunction, abnormalities of sexual development, and nutritional troubles may contribute to the development of osteoporosis. It must be acknowledged that both pediatric and adult DS cohorts display a low level of physical fitness [4].

Clinical assessment of osteoporosis relies mainly on bone mineral density (BMD) measurements using dual-energy X-ray absorptiometry (DXA). The quantitative bone ultrasound (QUS) technique can also discriminate between normal and osteoporotic women [5] with a sensitivity similar to densitometry techniques. DXA does not provide any information on bone structure and matrix factors. QUS variables, in addition to bone density [6], also depend on bone structure and composition. QUS is a recognized alternative noninvasive technique that measures some characteristics of bone quality such as microarchitecture, elasticity, and density [7].

The link between muscle and bone ("functional muscle—bone unit") is well described [8]. The key idea is the analysis of bone parameters within the context of muscle function. In this way, Schoenau [9] proposed a two-stepped diagnostic algorithm to characterize metabolic bone diseases in children and adolescents. Individuals who are characterized by a normal muscle mass in relation to their stature, but have insufficient bone mass in relation to muscle mass, are subjected to a primary bone disease. By contrast, secondary bone diseases are defined by a correct bone modeling process in combination with a decreased muscle mass or function. Muscle contraction places the greatest physiological load on bone, and so the strength of bone must adapt to muscle strength [10]. It can be argued that deficiencies in muscle contraction represent the major cause of bone weakness (secondary bone disease). Therefore, if muscle hypotonia is reported in patients with DS, a resulting osteopenia would be observed.

The aim of this study was to assess the skeletal status of individuals with DS using the quantitative ultrasound technique. A second purpose was to relate these ultrasound parameters to body tonicity. Although body tonicity is not readily quantifiable, we chose to assess it by stabilometric measurements. Stabilometry is a valid, objective, and functional evaluation of the postural control system in its steady-state behavior.

Methods

Participants

All active individuals with DS were eligible for recruitment into this study, which was conducted in France and Romania using the same ambulatory devices. A group of 193 patients with DS (104 males and 89 females) aged between 8 and 37 years participated in this study. Concomitantly, we measured a total of 246 healthy individuals (107 males and 139 females) aged between 10 years and 61 years. Measurements were performed with support from the Special Olympics Organization and French Federation of Adapted Sport. Written informed consent was obtained from all parents or participants. The study had obtained agreements from the ethical committee of Bucharest University (UNEFS) and the medical department of Adapted Sport Federation in France.

Anthropometric measurements

Body height was measured with a standard stadiometer (Holtain Ltd., Crymych, UK) and body mass on a balance-beam scale (SECA 709; Seca, Hamburg, Germany).

QUS measures

The Achilles Insight (GE, Lunar Corporation, Madison, WI, USA) is a quantitative ultrasound imaging device, which allows quick production of real-time images of the heel bone. Broadband ultrasound attenuation (BUA) and speed of sound (SOS) values are measured in a circular region of interest (ROI). The ROI programmed by the manufacturer of the Achilles has a diameter of 25 mm, the same size as the transducer. It allows the acquisition of a circular ROI of around 80 mm.

A closed-water system provides dynamic coupling. Alcohol was applied, as a coupling agent, to the surface of the calcaneus skin in order to facilitate the propagation of ultrasound beam. In some cases, the ultrasound signal does not reach the receiving transducer, resulting in a value out of range. This can occur when bone mass is either extremely high or extremely low, and the signal is therefore not measurable.

Because there is no consensus on whether the dominant or nondominant foot should be used to measure BMD or