Journal of Clinical Densitometry: Assessment & Management of Musculoskeletal Health, vol. ■, no. ■, 1–9, 2017

1094-6950/■:1–9/$36.00
http://dx.doi.org/10.1016/j.jocd.2017.05.006

Original Article

Assessment of Bone Mineral Density at the Distal Femur and the Proximal Tibia by Dual-Energy X-ray Absorptiometry in Individuals With Spinal Cord Injury: Precision of Protocol and Relation to Injury Duration

Stacey Lobos,[1] Anne Cooke,[2] Gillian Simonett,[3] Chester Ho,[3,4] Steven K. Boyd,[2,5] and W. Brent Edwards,[1,2,3]*

[1]Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Calgary, Canada; [2]McCaig Institute for Bone and Joint Health, University of Calgary, University of Calgary, Calgary, Canada; [3]Division of Physical Medicine and Rehabilitation, Department of Clinical Neurosciences, University of Calgary, Calgary, Canada; [4]Hotchkiss Brain Institute, University of Calgary, Calgary, Canada; and [5]Department of Radiology, Cumming School of Medicine, University of Calgary, Calgary, Canada

Abstract

Spinal cord injury (SCI) is characterized by marked bone loss at the knee, and there is a need for established dual-energy X-ray absorptiometry (DXA) protocols to examine bone mineral density (BMD) at this location to track therapeutic progress and to monitor fracture risk. The purpose of this study was to quantify the precision and reliability of a DXA protocol for BMD assessment at the distal femur and the proximal tibia in individuals with SCI. The protocol was subsequently used to investigate the relationship between BMD and duration of SCI. Nine individuals with complete SCI and 9 able-bodied controls underwent 3 repeat DXA scans in accordance with the short-term precision methodology recommended by the International Society of Clinical Densitometry. The DXA protocol demonstrated a high degree of precision with the root-mean-square standard deviation ranging from 0.004 to 0.052 g/cm^2 and the root-mean-square coefficient of variation ranging from 0.6% to 4.4%, depending on the bone, the region of interest, and the rater. All measurements of intra- and inter-rater reliability were excellent with an intraclass correlation of ≥0.950. The relationship between the BMD and the duration of SCI was well described by a logarithmic trend (r^2 = 0.68–0.92). Depending on the region of interest, the logarithmic trends would predict that, after 3 yr of SCI, BMD at the knee would be 43%–19% lower than that in the able-bodied reference group. We believe the DXA protocol has the level of precision and reliability required for short-term assessments of BMD at the distal femur and the proximal tibia in people with SCI. However, further work is required to determine the degree to which this protocol may be used to assess longitudinal changes in BMD after SCI to examine clinical interventions and to monitor fracture risk.

Key Words: Bone mineral density; disuse osteoporosis; dual-energy X-ray absorptiometry; knee; reliability.

Introduction

Spinal cord injury (SCI) is associated with a number of secondary complications, including a rapid and considerable loss of bone mineral density (BMD) from sublesional skeletal locations *(1,2)*. Motor impairment plays an important role in BMD loss, wherein people with motor complete SCI tend to lose more BMD than individuals with

Received 01/24/17; Revised 04/25/17; Accepted 05/15/17.
*Address correspondence to: W. Brent Edwards, PhD, Human Performance Laboratory, Faculty of Kinesiology, University of Calgary, Calgary, KNB 418, 2500 University Dr. NW, Calgary, AB T2N 1N4, Canada. E-mail: wbedward@ucalgary.ca

motor incomplete SCI (3,4). Unlike individuals with primary osteoporosis (5), or certain endocrine disorders (e.g., malnutrition, disordered vasoregulation, and hypercortisolism) (6), the greatest loss in BMD after SCI is observed around the regions of the knee. Within the first 2–3 yr of SCI, approximately 50% of the BMD is lost from the distal femur and the proximal tibia (1,7).

The clinical significance of BMD loss after SCI is an increased risk of fracture (8,9). Coincident with the locations of greatest BMD loss, these fractures most frequently occur at the distal femur and the proximal tibia (8,10). Most fractures after SCI are considered low-energy, or fragility, fractures because they are associated with minimal to no trauma, such as falls from wheelchairs, transfer activities, stretching, and even rolling over in bed (11–13). In some instances, active therapy protocols designed to strengthen the musculoskeletal system in SCI patients (14,15) have caused fracture (16,17), thereby hindering the ability to reverse or attenuate losses in BMD. Fractures after SCI that often result in long periods of hospitalization (usually 7 times greater than non-fracture-related admissions) and discharge to a secondary facility rather than at home are common (11).

Unlike primary osteoporosis, there is no standard of care for the detection, prevention, or treatment of SCI-related bone loss. Medical professionals have reported major barriers to bone loss therapy, including the lack of standardized methodologies for monitoring BMD in the SCI population (18). Current dual-energy X-ray absorptiometry (DXA) protocols for the general public are inadequate for the SCI population, in part, because the locations of routine fracture do not correspond between these 2 groups (1,19) and the *T*-scores defining elevated fracture risk in able-bodied adults are characteristic of most people with SCI (20). A limited number of DXA protocols have been proposed for measuring BMD at the knee in individuals with SCI. Methods based on existing manufacturer algorithms (e.g., spine and forearm protocols) have illustrated high reliability (21,22), and this is important for assessing longitudinal changes in, or making clinical recommendations based on, BMD measurements.

Measurement precision will vary by clinical center (depending on the operator, the patient positioning, the analysis routine, and the instrument quality control) and patient population (depending on the degree of BMD) (23). The purpose of the present study was to quantify the precision and reliability of a DXA protocol for BMD assessment at the distal femur and the proximal tibia in individuals with SCI. To this end, a short-term precision assessment was conducted on both individuals with SCI and a reference group of able-bodied controls. The protocol was subsequently used to investigate the relationship between the BMD and the duration of SCI.

Methods

Study Participants

Nine individuals with SCI and 9 able-bodied controls (Table 1) participated in the present study following the approval of institutional ethics and written informed consent. No inclusion-exclusion criteria were based on sex, race, or ethnicity. Individuals with acute SCI (<1 yr) were recruited from the inpatient population, or as outpatients during early routine follow-ups, at the Foothills Medical Centre in Calgary, Alberta. Individuals with chronic SCI (>1 yr) were recruited from surrounding SCI outpatient clinics. All participants with SCI were medically stable in the opinion of their physiatrist and were 21 yr of age or older to ensure a population with closed epiphyses. The participants with SCI were nonambulatory, with an American Spinal Injury Association impairment scale level of A, B, or C at study entry. A reference group of able-bodied controls were recruited and matched with SCI participants based on self-reported age, height, and weight (Table 1). All participants had no prior surgery, fracture, or heterotopic ossification on the right knee. Pregnant females and patients with current or recent (within 12 mo) use of drugs that affect bone metabolism (bisphosphonates, parathyroid hormone, and selective estrogen receptor modulators) were excluded from participation.

DXA Acquisition and Analysis

DXA scans at the distal femur and the proximal tibia were acquired and assessed using a similar version of the protocol, as well as an associated positioning device, to that developed and utilized at the Bone Density Lab at the Lyndhurst Centre, Toronto Rehabilitation Institute (24). In our modified version, DXA scans were obtained using a GE Lunar iDXA scanner (GE Medical Systems Ultrasound & Primary Care Diagnostics, LLC, Madison, WI) with integrated software (enCORE Version 14/16; GE Healthcare, Madison, WI). A medical radiation technologist (MRT) who was registered with the applicable local provincial regulatory body acquired all scans. One specific MRT was consistently present for all scans, although decisions in positioning and scan acquisition were made either by this MRT alone or collaboratively with 1 of 2 other MRTs. The participants with SCI manually transferred themselves, or were assisted with the use of a slide board or mechanical lift, from their wheelchair or stretcher to the DXA table. The participants were asked to lay supine on the DXA table with their lower limbs extended, after which a custom-fabricated acrylic-polycarbonate device was fitted to the participants' right leg, and a foam piece was positioned under the knee (Fig. 1). The device maintained the right leg's internal rotation and extension chosen by the MRTs and reduced movement during scan acquisition.

The distal femur and the proximal tibia of the right leg were captured as separate imaging fields using the manufacturer's existing AP lumbar spine protocol on a thin scan mode. This scan mode uses a 64-channel detector and a fan beam of 0.625 mA (±20%) and 100 kV (±5%). The average irradiation time for a 15.8 × 12.0 cm image is 30 s. For the present study, the scan length and width were increased to 19 and 14 cm, respectively. Ideal scans demonstrated a straight femoral-tibial joint line (with the patella above this joint line) and a minimal overlap between the fibular