INTRODUCTION

Osteoporosis is a major health concern for older adults. As bone mineral density (BMD) is linked to skeletal loading and walking is the most common weight-bearing activity in older adults, walking has been extensively promoted for the prevention of osteoporosis. The amount and intensity of walking to maintain a healthy skeleton, however, is unknown and thus, in the context of skeletal health, evidence to support a specific target of steps per day is lacking.

The Bone Density Index (BDI) [1, 2] offers an opportunity to examine the influence of a daily walking regimen on bone health. With this index, it is possible to investigate the effects and interactions of body weight and habitual walking activity patterns, since the BDI includes a weighting factor for the relative importance of the number of loading cycles versus the magnitude of loading. The BDI has been shown to correlate with calcaneus BMD in healthy women [1] and with proximal femur BMD in a group of subjects with chronic stroke [2].

The purpose of this study was to test for a correlation between the BDI and BMD at the proximal femur in healthy, post-menopausal females. This relationship between BDI and BMD was used to predict, for a range of body weights and walking speeds, the number of steps per day necessary to maintain a range of BMD values. These data were used to test the hypothesis that 10,000 steps per day are sufficient to maintain a healthy BMD for females with different body weights (BW).

METHODS

Gait mechanics, habitual walking activity and BMD were quantified for 66 healthy post-menopausal females, (age 50 to 64 yrs). Subjects provided informed consent prior to participation per an approved Stanford University IRB protocol. Free-living steps per day and walking speed were measured using an activity monitor (AMP231/331, Dynastream Innovations, Canada) worn for five days. The loading cycles for a given hip are one half of the total step count; therefore, activity monitor totals were divided by 2 to obtain steps per leg per day. Lower extremity kinematics and ground reaction forces (GRF) were collected as subjects walked at slow, medium and fast speeds in a gait laboratory. BMD was quantified for the total femur region of interest using DXA (GE/Lunar iDXA). The T-scores (BMD normalized by the young adult reference BMD value) were calculated by the scanner software. A T-score ≥ 1 is considered normal, a T-score < 1 and > 2.5 indicates low bone density or osteopenia, and a T-score ≤ 2.5 indicates osteoporosis.

The bone stimulus, BDI, was determined using a mathematical model of bone density regulation [1]:

\[ BDI = \left( n_{steps} \times (\beta \times GRF)^m \right)^{1/m}, \]

where \( m = 6 \) is an empirically determined constant; \( n_{steps} \) = average steps per leg per day; \( \beta = BW/\text{mean BW of cohort} \). The GRF value was estimated for each subject using the activity monitor walking speed history and a linear regression equation determined for walking speed and GRF from the gait analysis. A linear regression model was used to investigate the relationship between BDI and BMD. Using the regression equation, the number of habitual daily steps was calculated for different T-score values and different values of body weight (\( \beta \)).

RESULTS

There was a significant correlation (\( p < 0.001; r^2 = 0.19 \)) between BMD and BDI (Fig. 1). The number of steps per leg per day in this mid age female cohort ranged from 1,292 to 9,510, with average free-living walking speeds ranging from 0.62 to 1.38 m/s.

Required step totals were calculated for the approximate range of BMD values spanned by the regression shown in Fig. 1 assuming an average free-living walking speed of 1.01 m/s. To maintain a T-score = -1.00, an individual with the average weight from our cohort (mass = 65.1 kg, \( \beta = 1.00 \)) would require 4,892 steps/day. Substantially more steps per day are required for lighter individuals (18,568 steps/day for mass 52.5 kg; \( \beta = 0.8 \)) and fewer steps per day for a heavier individual, (1,638 steps/day for mass 78.7 kg; \( \beta = 1.20 \)) (Fig 2).

Walking speed is one modifiable variable that could potentially be used to increase the loading stimulus and decrease the number of steps per day needed in an intervention. For the lower weight individuals (BW 20% lower than average) only with an average walking speed greater than 1.32 m/s is 10,000 steps per day sufficient to maintain a T-score = -1.0.

REFERENCES


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