

# HIP JOINT MOMENTS DURING WALKING AND BONE MINERAL DENSITY IN HEALTHY OLDER WOMEN

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## INTRODUCTION

The relationship between proximal femoral bone density and the stress stimulus provided by normal walking is of interest because of the relationship between bone mineral density (BMD) and fracture risk in falls. While, body strength, exercise and ambulation have been suggested (Snow-Harter et al., 1992; Yanagimoto et al., 2000) as important factors in the maintenance of bone mass at the hip, it remains unclear if there are specific characteristics of walking that influence BMD to a greater extent than static characteristics such as body weight. During walking the joint moments are major factors influencing the hip joint load as they are balanced by muscle forces. Thus it is useful to consider how the variations in the dynamic moments influence the variation in BMD. The purpose of this study was to test the hypothesis that the dynamic moments during walking are a stronger predictor of BMD than the static effect of purely body weight using previously developed theoretical relationships between applied stress and bone density.

## METHODS

Kinematic, kinetic, and bone density data were collected for 22 healthy, older women (age: 63.4 +/- 1.6 yrs; height: 1.64 +/- 0.01 m; mass: 64.3 +/- 2.5 kg). All subjects provided informed consent according to the Stanford institutional review board. Subjects walked along an 11m long walkway with an embedded force platform

(4060H, Bertec Corp.) at a self-selected normal walking speed. Motion data were collected with an optoelectronic system (ProReflex 240, Qualisys Inc.). Both force and motion data were captured synchronously at 120Hz. Only subjects who did not participate in high-impact type sports were included, thus measures of the net joint moments and forces during the gait test were expected to be representative of habitual hip joint loading patterns.

An inverse dynamics approach was used to calculate external moments at the hip. The RMS joint moment was calculated from the directional components. BMD ( $\text{g}/\text{cm}^2$ ) of the proximal femur was quantified using dual-energy X-ray absorptimetry (Hologic QDR-1000W).

A relationship between effective stress and apparent density has previously been shown (Carter et al., 1987):

$$\sigma \propto \rho^2.$$

Introducing a simplified measure of stress, we obtain:

$$\frac{F}{A_{neck}} \propto \rho^2.$$

Using scaling principles this relationship can be extended to a theoretical relationship between surrogate measures of the hip joint force and the BMD, where the measured BMD is related to the apparent density as (Carter et al., 1992):

$$\rho \propto \frac{BMD}{\sqrt{A_{neck}}} \propto \frac{BMD}{h}$$

Therefore, the relationship between the joint force and the BMD is:

$$\frac{BMD}{h} \propto \sigma^{1/2} \propto \left( \frac{F_{hip}}{A_{neck}} \right)^{1/2}$$

$$BMD \propto F_{hip}^{1/2}.$$

In walking

$$M \propto BW * h \text{ and } F_{hip} \propto M/h.$$

Therefore,

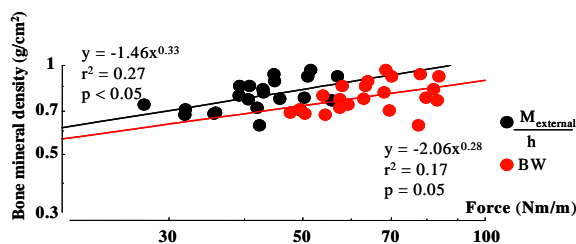
$$\rho \propto \left[ \left( \frac{M}{h} \right) / h^2 \right]^{1/2}$$

$$BMD \propto \left( \frac{M_{external}}{h} \right)^{1/2},$$

where  $F_{hip}$  = force in hip joint  
 $A_{neck}$  = cross sectional area of hip  
 $M$  = joint moment  
 $h$  = height  
 $\sigma$  = effective stress  
 $\rho$  = bone apparent density.

## RESULTS AND DISCUSSION

There was a significant relationship between the dynamic  $M_{external}/h$  and BMD (Figure 1). After performing a log-log transformation, the slope of the regression of BMD vs.  $(M/h)^{1/2}$  was found to be 0.33 (95% CI: 0.07- 0.58;  $p < 0.05$ ). While significant, the relationship was not as strong when mass was used in place of the moment. The slope is 0.28 (95% CI: 0.00- 0.56;  $p = 0.05$ ;  $r^2 = 0.17$ ) for  $F_{hip} \propto BW$ .



**Figure 1:** A log-log plot of BMD vs the resultant joint moment divide by height and BMD vs. body weight.

## SUMMARY/CONCLUSIONS

This study demonstrated that the relation between BMD, joint moment and body size explained more variance than a relationship between BW and BMD. The fact that joint moments are most closely related to muscle forces and therefore the dynamic joint forces in walking suggests that the dynamics of walking play an important role in the maintenance of bone density at the hip and the resultant joint moment can be a useful predictor of BMD. In addition, these results indicate that interventions that modify the joint moments may have an impact on BMD.

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