

# Pedometer Measured Step Counts and Bone Mineral Density among Premenopausal Women

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**Abstract** Pedometers have become popular physical activity measurement tools and have proven to be valid and reliable. Opportunity for bone impact comes mostly from weight bearing physical activity and is captured by the use of these devices. However, there is question about the intensity of impact needed to stimulate changes in bone tissue. Research focused on walking activity, which comprises a majority of daily physical activity for most individuals, has resulted in conflicting effects on the commencement of bone tissue remodeling. The purpose of this study was to measure pedometer based daily physical activity and determine whether these data significantly correlate with aBMD (areal bone mineral density) ( $\text{g}/\text{cm}^2$ ) measures among premenopausal women. A secondary purpose was to look specifically at the relationship between moderate intensity level data and aBMD. Forty-two pre-menopausal women from central Minnesota participated in the summer of 2011. Body mass index, calcium, vitamin D, total, and moderate intensity steps were tallied, and hip and lumbar spine aBMD was measured. Significant bivariate correlations ( $p < .05$ ) were found between calcium and femoral, lumbar spine, and L2 aBMD measures. No correlations were found between age or vitamin D intake and aBMD measures. Significant bivariate correlations were also found between body mass index and L1, L3, L4, and total hip aBMD. No significant bivariate correlations were found between aBMD measures and total step or moderate intensity counts. Partial correlations, controlling for calcium and body mass index, did not reveal any correlations between total or moderate step counts and aBMD. It is plausible to conclude that the Omron HJ-303 pedometer may not be an appropriate tool for tracking bone building activity. Researchers need to continue to look for a consumer tool that effectively tracks this type of activity for those interested in improving bone health.

**Keywords:** osteoporosis, activity monitor, bone remodeling

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## 1. Introduction

Osteoporosis continues to be a condition impacting a significant number of individuals. Worldwide, osteoporosis affects an estimated 200 million women [1]. Much of the research done in this area focuses on modifiable factors that either improve or decrease bone mineral density [2]. Each of these projects moves closer to establishing recommendations for improving and maintaining bone health but researchers continue to call for more evidence [3].

Traditionally older women have been the focus of inquiries related factors affecting bone health. In recent years, more work has looked at how lifestyles factors impact bone mineral density among a younger, premenopausal, female population. In addition, premenopausal women were chosen for this project in an effort to more clearly understand the potential relationship between pedometer-based physical activity and bone mineral density (BMD). It is well known that the physiological and hormonal events of menopause have a significant impact on BMD which can complicate this understanding [4].

It is well known in the literature that bone mineral density responds specifically to the impact placed upon on it [3,5]. There is still question related to how intense the impact needs to be in order for bone to respond and get stronger. Evidence does strongly suggest that bone responds more strongly to irregular, high impact, high magnitude loading [3] so in order for improvements in bone mineral density to be seen, activity may need to be more intense than activities of daily living. From a practical perspective, this type of weight-bearing activity can be difficult to measure without the use of force plates and constant monitoring. One potential tool that could be used to measure bone responsive activity in everyday activity is with the use of a pedometer.

Opportunities for bone impact typically come from weight-bearing physical activity and would be captured by the use of a pedometer. The use of pedometers has become popular among individuals interested in tracking their daily physical activity (PA) participation and these devices have proven to be valid and reliable [6]. The devices are available in a variety of models that capture activity in multiple planes of action. However, there is a need for more literature using pedometer technology as a

source of activity measurement for bone health [7]. Some existing literature has found no connection between step counts and BMD while other literature has [5,7,8]. With good reason, researchers have continued to ask for more clarity on this topic [7].

Outcome variables displayed by many pedometers often include steps, distance, and calorie expenditure. One challenge with using pedometer technology is that such a wide variety of devices are being used. These can vary in plane of action and intensity of activity captured. However, what we do know is that a pedometer is a tool that can be used by almost anyone and can provide feedback to its user. If a PA protocol could be established using a commercially available pedometer that is associated with improvements or maintenance of bone mineral density, it could provide needed clarity.

The purpose of this study was to examine the relationship between PA, as measured by a pedometer, and areal bone mineral density (aBMD) among premenopausal women.

## 2. Methods

### 2.1. Experimental Approach

Currently, it is unclear whether pedometer-determined PA is related to aBMD measures. This investigation used 7-day pedometer-measured step counts to estimate PA volume, along with aBMD measures at clinically relevant sites. The aBMD data served as the main dependent variables. The pedometer chosen also highlights moderate intensity step counts in addition to total step counts which was of particular interest to the investigators in this study. Correlations among these variables, controlling for relevant confounding factors when appropriate, were computed in an attempt to answer this question.

#### 2.1.1. Participants

A total of 42 pre-menopausal women ( $38.69 \pm 7.95$  years) participated in this study. Participants were recruited from employee e-mail lists and word-of-mouth and participated voluntarily. All participants self-reported having a regular menstrual history. In addition, all participants responded "No" to a question asking them if they were experiencing any signs of menopause at the time of the study. Prior to recruitment and participation, University Institutional Review Board approval was obtained. All participants read and signed an Informed Consent document at the start of the project.

#### 2.1.2. Procedures

Height was measured using a Detecto Physician Scale using a mechanical height rod (Web City, MO), and body weight in kg was measured using a Health-o-Meter digital scale, Model number 599KL. All participants were asked to remove their shoes during the height and weight measurements.

Body composition was estimated using the Omron HBF 306 Body Logic Pro Body Fat Analyzer, according to the manufacturer instructions. This device has shown reasonable validity if used among a relatively homogeneous group of

participants, as was the case in the present study [9]. Participants were not required to follow any additional protocol instructions prior to having their body composition measured.

Total daily steps and moderate intensity steps were tallied for a 7-day period using the Omron HJ-303 Tri-axis pocket pedometer. This specific pedometer was chosen for this study because of its ability to capture moderate level step counts in addition to overall step counts. According to the Omron instruction manual, moderate steps include any activity at or above 100 steps per minute [12]. Prior BMD and pedometer based research studies have included recommendations related to intensity level and therefore we felt it was an important factor consider in the present study [11].

Participants were asked to wear the pedometer according to the manufactures instructions on their waist from the time they woke until they went to sleep at night, making exceptions only for situations where the device may come in contact with water. By nature, a pedometer captures PA that is weight-bearing, therefore it will not pick up on activities such as cycling. Pedometers also cannot be worn in the water to track swimming or diving activities. The validity of this particular device has preliminarily been investigated under a variety of activity types, and when compared to other similar devices, the Omron HJ-303 pedometer, worn on the waist was the most accurate [13].

Dietary intake was assessed using a 3-day dietary log. Dietary logs were input into the web platform FitDay.com to assess dietary intake values, including calcium and Vitamin D. The validity of a 3-day dietary log has been established [14].

Hip and lumbar spine aBMD were assessed by a licensed technician using a Hologic DEXA, model QDR 4500 Elite, S/N 49865 (Bedford, Massachusetts). The manufacturer's standard protocol was followed to acquire the scans. Lumbar spine aBMD was determined by imaging lumbar vertebra one through four (L1-L4), which included the body of the vertebra, the pedicles, lamina, spinous process, and transverse processes. Right and left hip scans included the femoral neck, trochanteric region, the bone shaft, and Ward's triangle. Prior to data collection each day, quality control calibrations were conducted using spine and step phantoms. All quality control measures fell within  $\pm 1.5\%$  of the mean, as required by the manufacturer. Participants were asked to remove all metal from their bodies and to wear cotton scrubs to avoid false images on the scan.

#### 2.1.3. Statistical Analyses

SPSS version 21 (SPSS, Inc, Chicago, IL, USA) was used to calculate all statistical analyses. Means and standard deviations of the anthropometric data are presented in Table 1. Bivariate correlations were computed among all study variables. Partial correlations were then conducted between all aBMD measures, moderate step counts, and total step counts, while controlling for any physiological variable that was significant in the bivariate analysis. Statistical significance was determined at the  $p < .05$ .

### 3. Results

Descriptive statistics for the sample appear in Table 1. The average step count accumulated in this sample of premenopausal women was 8,782.28 ( $\pm$  2,996.45). All participants wore the device for the full seven day study period.

Pearson Product Moment correlations revealed a significant correlation ( $p < .05$ ) between average calcium intake and average femoral neck aBMD ( $r = .44, p = .00$ ), average lumbar spine aBMD ( $r = .32, p = .04$ ), and L2 aBMD ( $r = .31, p = .04$ ) aBMD. No significant correlations were found between age or average vitamin D intake and any of the aBMD measures. Significant correlations were found between BMI and L1 aBMD ( $r = .32, p = .04$ ), L3 aBMD ( $r = .34, p = .03$ ), L4 aBMD ( $r = .32, p = .04$ ), and total hip aBMD (THD) ( $r = .35, p = .02$ ). No significant relationships were found between aBMD measures and total step count or between aBMD measures and moderate intensity step counts, before or after controlling for the effects of calcium intake and body mass index (BMI). Because no significant bivariate correlations were seen between age or vitamin D and any

of the aBMD measures, we did not control for these variables. Bivariate correlation coefficients for key variables in this study are shown in Table 2.

**Table 1. Physical Characteristics of Participants (n = 42)**

Characteristics	<i>M</i>	<i>SD</i>
Age (yrs)	38.69	7.95
Height (in)	64.90	2.60
Weight (kg)	70.65	12.30
BMI (kg/m <sup>2</sup> )	26.06	4.87
THD (g/cm <sup>2</sup> )	1.07	0.16
FND (g/cm <sup>2</sup> )	1.03	0.16
L1 (g/cm <sup>2</sup> )	1.20	0.19
L2 (g/cm <sup>2</sup> )	1.27	0.21
L3 (g/cm <sup>2</sup> )	1.31	0.19
L4 (g/cm <sup>2</sup> )	1.27	0.18
Calcium (mg)	991.60	323.66
Vitamin D (mcg)	2.81	2.40
Average Steps	8,782.28	2,966.45
MOD Steps	4,371.80	2,055.48

Note. BMI = Body mass index; THD = Total hip aBMD; FND = Femoral neck aBMD; LSD = Lumbar spine aBMD; Calcium = Average dietary calcium intake; MOD steps = Average moderate intensity steps.

**Table 2. Bivariate Correlations among Study Variables (n = 42)**

	L1	L2	L3	L4	Ca	Steps	Mod	THD	FND	BMI	AGE	VitD
L1 (g/cm <sup>2</sup> )	.96**	.92*	.88**	.25	-.17	-.18	.75**	.71**	.32*	-.02	.04	
L2 (g/cm <sup>2</sup> )		.94**	.88**	.31*	-.15	-.12	.77**	.73**	.28	-.04	.10	
L3 (g/cm <sup>2</sup> )			.94**	.29	-.10	-.12	.83**	.76**	.34*	-.05	.03	
L4 (g/cm <sup>2</sup> )				.27	-.18	-.20	.85**	.79**	.32*	-.01	.05	
Ca (mg)					.20	.27	.32*	.44**	-.09	-.26	.59**	
Steps						.88**	-.10	-.04	-.06	-.12	.13	
Mod							-.06	.01	-.02	-.09	.11	
THD (g/cm <sup>2</sup> )								.93**	.35*	-.09	.09	
FND (g/cm <sup>2</sup> )									.19	-.23	.20	
BMI (kg/m <sup>2</sup> )										.32*	-.10	
Age (years)											-.15	
VitD (mcg)												

Note. L1–L4 = Lumbar spine aBMD; Calcium = Average dietary calcium intake; Step = Average daily steps; Mod = Moderate intensity steps; THD = Total hip aBMD; FND = Femoral neck aBMD; BMI = Body mass index; VitD = Average vitamin D intake.

\*  $p < .05$ ; \*\*  $p < .01$ .

### 4. Discussion

The purpose of the present investigation was to determine whether or not a relationship existed between pedometer measured step counts and aBMD at a variety of hip and spine locations. Pedometers are devices designed to measure weight-bearing PA. These devices have become popular tools among individuals interested in tracking their PA. Researchers use these tools to sample behavior patterns, which have been used to determine health levels of step counts for a variety of populations [15]. Average step count in this sample averaged 8,782.28 ( $\pm$  2,966.45), which falls within the general health related PA guidelines established for step counts. Research on the use these devices for measuring PA has shown that while some variability exists, these tools are valid and accurate if used appropriately [6].

Calcium availability and healthy aBMD levels are positively related and have been heavily researched [16].

While not a major outcome of this research, it is important to note that average calcium intake fell within recommended levels. However, average vitamin D intake was below recommended levels [10]. Significant bivariate correlations were found between average calcium intake and hip and spine aBMD measures (see Table 2).

It is well known that aBMD responds to dynamic stress placed on it [17]. As stress is detected by skeletal tissue, bone remodeling begins. As long as adequate intermediaries are present, bone tissue will respond to stress by reinforcing itself, thus increasing aBMD levels [18]. Much of the current research has been focused on exactly how much stress is needed before bone remodeling takes place [19]. Some investigators have reported stress levels greater than that obtained from regular activities of daily living are needed to begin remodeling [18].

The Omron HJ-303 was chosen for this study because of its ability to capture moderate level step counts in addition to overall step counts. According to Omron,

moderate intensity steps are detected when frequency of steps hits 100 or more counts per minutes [12]. By focusing our attention on these higher frequency step counts, we were hoping to see a relationship between this more sensitive level of step count and aBMD. Much of the current research on pedometers-measured PA has shown significant reductions in risk of fracture at the hip [20,21] and a conservation of aBMD levels [22], but there is less evidence to show a relationship between pedometer counts and aBMD. We found no significant relationship between step counts and any of the aBMD sites.

Considering the significant correlation found between calcium and BMI on a variety of aBMD measures among this sample of premenopausal women, we ran a partial correlation between step count and moderate step count while controlling for the effects of calcium intake and BMI. Again, no significant relationship was found between either average steps or average moderate intensity steps and any of the aBMD measures.

It seems reasonable to conclude that the moderate steps captured by the Omron HJ-303 were not the quality and/or the quantity needed to identify a relationship to aBMD in this study. Considering the operational definition of moderate steps by the manufacturer as a step frequency at or above 100 steps per minute rather than some level of force generated, the outcome is understandable. It is important to note, here at the conclusion, that the participants in this study were instructed to maintain what they would consider normal daily PA behaviors while wearing the pedometers, which may or may not have included intentional PA or exercise. Future research may look at more prescribed activity patterns along with the use of pedometers such as the Omron HJ-303 to see if perhaps a correlation could be found.

## 5. Conclusions

The outcome of the present investigation indicates that pedometer-measured PA, even from pedometers that highlight moderate intensity steps in addition to total steps, may not be the most representative tool to use if the goals is to identify a level of activity related to bone health. If bone health is a goal for individuals, the current guidelines from the International Osteoporosis Foundation include a variety of high-intensity jumping and weight-bearing activities, resistance training, along with high-impact aerobics [1]. Currently, PA guidelines for bone health are research design-specific and are difficult to apply outside of a research setting. This investigation was an attempt to take a step closer to a valid measurement tool that could have been used to clarify those guidelines. As more research is conducted, the pedometer used in this study and other measurement tools need to be re-examined with specific focus on bone health.

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## Statement of Competing Interests

The authors have no competing interests.

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