Research article

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Bone Health and its association with Physical Activity among Staff at Pham Ngoc Thach University of Medicine

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Abstract

Background: Osteoporosis is a significant public health issue, particularly in high-risk groups such as office workers. This study aimed to assess bone mineral density (BMD) and evaluate its association with physical activity and sedentary time among staff at Pham Ngoc Thach University of Medicine (PNTU).

Subjects: The study was conducted on 391 staff members at PNTU, including 130 males and 261 females, aged 23–69 years.

Methods: BMD was measured using dual-energy X-ray absorptiometry (DEXA) with the HOLOGIC HORIZON system. Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ) developed by the World Health Organization (WHO). Risk factors such as age, sex, diet, physical activity, and medical history were collected via a structured questionnaire. Data analysis was performed using R software, including descriptive statistics, BMD assessment by age and sex, and linear regression to evaluate associations between BMD, physical activity, and sedentary time.

Results: The prevalence of osteoporosis and low BMD was 6.8% and 3.5%, respectively, with females showing a lower prevalence than males. The rate of non-traumatic fractures was 2.3%. Key risk factors included a family history of fractures, alcohol consumption, inadequate calcium-vitamin D intake, and obesity. Females exhibited significantly lower physical activity duration and energy expenditure (1,920 vs. 3,280 MET-min/week) compared to males, while sedentary time was similar between sexes. No statistically significant differences were found in physical activity or sedentary time across BMD or age groups. Linear regression analysis revealed a statistically and clinically significant positive association between physical activity duration, energy expenditure, and BMD at the femoral neck and lumbar spine ($p<0.05$). However, no significant associations were observed between BMD and physical activity or sedentary time across subgroups.

Conclusion: The study recorded osteoporosis and low BMD prevalence rates of 6.8% and 3.5%, respectively, with a positive association between physical activity and BMD. The study population exhibited relatively good bone health, despite low calcium-vitamin D intake and high alcohol consumption. These findings suggest that, alongside increasing physical activity, additional lifestyle interventions are needed to prevent osteoporosis.

Keywords: Bone health, bone mineral density, occupational activities, physical activity, sedentary time.

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1. INTRODUCTION

Osteoporosis is a global and national public health concern due to its large scale and severe consequences, particularly fractures, which become increasingly significant with rapid population aging [1]. Osteoporotic fractures are estimated to cost approximately $17.9 billion annually in the United States and £1.7 billion in the United Kingdom [2].

Peak bone mass, achieved in youth, is the strongest predictor of osteoporosis risk later in life [3]. Maximizing peak bone mass is recommended as one of the most effective ways to prevent osteoporosis [3] . Thus, just as osteoporosis reflects poor bone health in older adults, low BMD in younger individuals is a warning sign of bone health issues, with both conditions carrying a high risk of non-traumatic fractures [4]. A comprehensive evaluation of bone health in a population should include low BMD in young individuals, osteoporosis in older adults, and non-traumatic fractures.

Peak bone mass is limited by genetic factors, but environmental and lifestyle factors also significantly influence its potential [5]. The bone-forming effects of physical activity and exercise have long been recognized [6], while a lack of physical activity is an established risk factor for osteoporosis [7]. This lack of activity, often referred to as "sedentary behavior" (SB), is defined as any activity with low energy expenditure (≤1.5 METs) in a sitting, reclining, or lying position [8]. Recent epidemiological and laboratory studies have shown that sedentary behavior, such as prolonged sitting common among office workers, negatively impacts bone health, independent of physical activity levels [9, 10].

Office workers, who typically spend prolonged periods sitting, are considered a sedentary group with low physical activity levels and are at high risk of adverse bone health outcomes [11]. While BMD has been extensively studied in older populations, research on younger individuals, particularly office workers at high risk of bone loss, is limited.

In this context, we conducted this study to assess bone health among staff at PNTU and evaluate the association between bone health and daily physical activity and sedentary time.

2. METHODS

2.1. Study Design: Cross-sectional.

2.2 Study Population:

Participants were staff members at PNTU, selected from a list of 895 employees provided by the Human Resources Department. To ensure a representative sample, systematic random sampling was applied. The minimum sample size was calculated based on three objectives: (1) determining the average BMD of PNTU staff, (2) estimating the prevalence of osteoporosis, and (3) assessing the association between physical activity, sedentary time, and bone health.

For objective (1), the sample size formula for estimating a mean was used with parameters: $\alpha=0.05$, $Z(1-\alpha/2) =1.96$, and mean BMD and standard deviation (σ) from the Vietnam Osteoporosis Study (VOS) (12) as 0.70 g/cm² and 0.12 g/cm², respectively. The minimum sample size was calculated as 46.

For objective (2), the sample size formula for estimating a proportion was used. As no prior data on BMD disorders among staff were available, P=50% was chosen to maximize sample size (P=0.5). With a significance level of p=5% and allowable error of d=5% ($\alpha=0.05$, d=0.05), the minimum sample size was calculated as 385.

For objective (3), the sample size formula for linear regression was used with parameters: $\alpha=0.05$, $Z(1-\alpha/2) =1.96$, power $(1-\beta) = 0.8$ ($Z(1-\beta) = 0.84$), and a regression coefficient between BMD and physical activity time (r=0.2) based on Chastin (2014) [11]. The minimum sample size was calculated as 199.

Thus, the minimum sample size ensuring statistical power was 385. Accounting for a 1% loss to follow-up and rounding, the study selected a sample size of 390 participants.

2.3. Inclusion Criteria: All PNTU staff who voluntarily agreed to participate and signed the informed consent form.

2.4. Exclusion Criteria: Individuals who did not complete the survey questionnaire or were ineligible for BMD measurement (e.g., pregnant women, individuals using iodine-, barium-, or radioactive isotope-containing contrast agents within the past 7 days).

To minimize bias from convenience sampling, systematic random sampling was used. With a target population of N=895 and a sample size of n=390, the sampling interval (k) was calculated as k=N/n≈2. A random starting point (r=1) was chosen, and participants were selected sequentially as r, r+k, r+2k, r+3k, etc. (i.e., 1, 3, 5, 7…) until the sample size of 390 was reached.

2.5. Data Collection

2.5.1. BMD Measurement: BMD was measured using the HOLOGIC HORIZON W DXA system (USA). The machine was calibrated with a phantom 30 minutes before each measurement session. Measurement sites were the femoral neck and lumbar spine. Osteoporosis was diagnosed based on WHO criteria:

- **For individuals aged ≥40 years**: T-Score was used:
  - Normal: T-Score ≥ -1
  - Osteopenia: -2.5 < T-Score < -1
  - Osteoporosis: T-Score ≤ -2.5
  - Severe osteoporosis: Osteoporosis + history of fracture.
- **For individuals aged <40 years**: Z-Score was used [13]:
  - Normal: Z-Score ≥ -1
  - Mildly low BMD: -2.0 < Z-Score < -1
  - Low BMD: Z-Score ≤ -2.0

Osteoporosis or low BMD was diagnosed when T-Score ≤ -2.5 or Z-Score ≤ -2.0 at ≥1 of the two sites (femoral neck or lumbar spine).

2.5.2. Physical Activity Assessment: Physical activity was evaluated using the WHO Global Physical Activity Questionnaire (GPAQ), developed in 2002 [14]. This tool measures three domains: workplace activities, transportation, and leisure activities. The duration and intensity (moderate or vigorous) of activities were recorded, and total activity time (minutes/week) and energy expenditure (MET-min/week) were calculated per WHO guidelines. Sedentary behavior was defined as activities with energy expenditure ≤1.5 METs in a sitting, reclining, or lying position (e.g., sitting at work, watching TV, reading, or using a computer). Sedentary time (minutes/week) was estimated as total weekly time minus moderate-to-vigorous activity time and sleep time, per GPAQ guidelines.

2.5.3. Risk Factor Assessment: A structured questionnaire collected the following data:

- **Personal information**: Name, age, sex, contact number, and workplace (department/center/unit).
- **Socioeconomic data**: Family status, education level, occupation.
- **Anthropometric data**: Age, height, and weight were measured using an electronic scale (Seca model 769; Seca Corp, CA, USA; accuracy: 0.1 cm for height, 0.05 kg for weight). Participants stood upright, barefoot, and in light clothing. Measurements were taken twice, and the average was used. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. BMI was classified per WHO criteria for Asians: underweight (<18.5), normal (18.5–22.9), overweight (23–24.9), obese (≥25) [15].
- **Gynecological data**: Age at menarche, menopause, use of contraceptives, or hormone replacement therapy.

- **Medical history**: Endocrine disorders (e.g., hyperadrenalism, hypogonadism, hyperthyroidism, hyperparathyroidism), kidney diseases (e.g., hypercalciuria, dialysis, deficiency of 1-hydroxylase in vitamin D metabolism).
- **Medication and supplement history**: Data on the use of medications (corticosteroids, contraceptives, hormones, calcium, vitamin D), alcohol consumption, smoking, and milk intake were collected via a structured questionnaire with 5 yes/no questions on medication use and 10 questions on the frequency and dosage of alcohol, smoking, and milk consumption.

2.5.4. Data Analysis

Data were cleaned, coded, and analyzed using R software to address the study objectives. Results were reported anonymously to ensure confidentiality.

Analysis included:

- Classification of bone health based on T-Score and Z-Score.
- Grouping bone health by age, sex, and BMI.
- Descriptive statistics (mean, standard deviation, median, percentage) to assess anthropometric, clinical, and BMD characteristics by age, sex, and BMI. Continuous variables were tested for normality using the Shapiro-Wilk test. Normally distributed variables were reported as mean ± standard deviation; non-normally distributed variables were reported as median [min, max].
- T-tests or ANOVA to compare BMD, physical activity time, sedentary time, and energy expenditure between groups.
- Univariate and multivariate linear regression to assess the association between BMD (dependent variable) and physical activity time, sedentary time, and energy expenditure (independent variables), adjusted for confounders such as age, sex, BMI, and medical history. Statistical significance was set at $p<0.05$.

2.5.5 Ethical Considerations

The study was approved by the PNTU Ethics Committee before implementation (Decision No. 1009/PNTU/REC, dated January 3, 2024). Participation was voluntary, and all participants signed an informed consent form. BMD measurements were provided free of charge, and participants with abnormal BMD results received counseling on prevention, monitoring, and treatment options

3. RESULTS

From a source population of 895 PNTU staff, 391 participants were recruited, including 261 females (aged 23–69) and 130 males (aged 23–69). The higher proportion of female participants was due to a higher female-to-male ratio in the target population (494 females vs. 401 males) and a higher refusal rate among males (30% vs. 2% in females). Anthropometric and clinical characteristics are presented in **Table 1**.

The average age of the study population was 42.6 years, with females being older than males (44 vs. 40 years). Most participants were of Kinh ethnicity (97%). Males had significantly higher rates of overweight (34.6% vs. 23.8%) and obesity (39.2% vs. 19.9%) compared to females. Smoking was not reported among females and was low among males (21.5%). Alcohol consumption was reported by 5.4% of females and 46.2% of males, with over 18% of males exceeding recommended alcohol limits. Approximately 45% of participants consumed milk, with no significant difference between sexes, but the average weekly milk intake was only 1.4 liters.

Table 1. Anthropometric and Lifestyle Characteristics

	Male (N=130)	**Female (N=261)**	**Total (N=391)**
Age			
Mean (SD)	40.0 (12.2)	44.0 (11.2)	42.6 (11.7)
Ethnicity			
Kinh	127 (97.7%)	253 (96.9%)	380 (97.2%)
Chinese	3 (2.3%)	7 (2.7%)	10 (2.6%)
Other	0 (0%)	1 (0.4%)	1 (0.3%)
BMI			
Mean (SD)	24.6 (3.38)	22.7 (2.89)	23.3 (3.19)
Thin	6 (4.6%)	18 (6.9%)	24 (6.1%)
Normal	28 (21.5%)	129 (49.4%)	157 (40.2%)
Overweight	45 (34.6%)	62 (23.8%)	107 (27.4%)
Obesity	51 (39.2%)	52 (19.9%)	103 (26.3%)
Smoking			
Currently	16 (12.3%)	0 (0%)	16 (4.1%)
Ever	12 (9.2%)	0 (0%)	12 (3.1%)
Never	102 (78.5%)	261 (100%)	363 (92.8%)
Smoking duration (years)			
Mean (SD)	18.7 (12.4)		
Pack-Day			
Mean (SD)	0.778 (0.877)		
Drinking	60 (46.2%)	14 (5.4%)	74 (18.9%)
Excessive alcohol use	11 (18.3%)	0 (0%)	11 (14.9%)
Drink milk	53 (40.8%)	121 (46.4%)	174 (44.5%)
Volume (liters/week)			
Mean (SD)	1.45 (1.55)	1.35 (2.88)	1.38 (2.54)

Clinical and gynecological characteristics of females showed an average age at menarche of 13.8 years, menopause at 51.1 years, and an average of 1.5 pregnancies (**Table 2**). The prevalence of 1–2 non-communicable chronic diseases was 15.3%, with no cases of ≥3 coexisting conditions. Common diseases included type 2 diabetes (1.5%), hypertension (8%), osteoarthritis (6.9%), asthma (2.3%), and cancer (1.8%). Regarding medications affecting bone health, females were more likely to use contraceptives or hormone replacement therapy (over 20%), calcium supplements (21.5%), and vitamin D (17%) compared to males. Only 3.1% reported a history of glucocorticoid use (**Table 2**).

Table 2. Clinical Characteristics

	Male (N=130)	Female (N=261)	Total (N=391)
Menarche			
Mean (SD)		13.8 (1.64)	
Menopause			
Postmenopause		68 (26.1%)	
Age mean (SD)		51.1 (3.65)	
Number of pregnancies			
Mean (SD)		1.46 (1.30)	
Co-morbidities	17 (13.1%)	43 (16.5%)	60 (15.3%)
≥ 3 Co-morbidities	0 (0%)	0 (0%)	0 (0%)
History of corticosteroid use	5 (3.8%)	7 (2.7%)	12 (3.1%)
History of calcium supplement	15 (11.5%)	56 (21.5%)	71 (18.2%)
History of vitamin D supplement	11 (8.5%)	44 (16.9%)	55 (14.1%)
History of anti-osteoporosis	1 (0.8%)	5 (1.9%)	6 (1.5%)
History of contraceptive use		45 (17.2%)	
History of hormone therapy		9 (3.4%)	

Objective 1: Assessment of BMD among PNTU Staff

BMD in females was lower than in males across both age groups (<40 and ≥40 years) and at both measurement sites (femoral neck and lumbar spine). However, the majority of participants in both sexes had normal BMD, particularly in the <40 age group (94.7%) (**Table 3**). In the ≥40 age group, the osteoporosis prevalence was 3.8%, with males showing a higher rate than females (5.4% vs. 3.1%). In the <40 age group, low BMD was more prevalent in males than females (4.6% vs. 1.1%)

Table 3. Characteristics of Bone Health

	Male (N=130)	Female (N=261)	Total (N=391)
Ages < 40	**68 (52.3%)**	**103 (39.5%)**	**171 (43.7%)**
Femoral Neck BMD			
Mean (SD)	0.835 (0.145)	0.748 (0.101)	
Lumbar Spine BMD			
Mean (SD)	0.933 (0.140)	0.865 (0.0996)	
Normal	54 (79.4%)	67 (65.1%)	121 (70.8%)
Mildly low BMD	11 (16.2%)	33 (32.0%)	44 (25.7%)
Low BMD	3 (4.4%)	3 (2.9%)	6 (3.5%)

	Male (N=130)	Female (N=261)	Total (N=391)
History of Fractures	14 (20.6%)	21 (20.4%)	35 (20.5%)
Family history of Fractures	5 (7.4%)	16 (15.5%)	21 (12.3%)
Ages ≥ 40	62 (47.7%)	158 (60.5%)	220 (56.3%)
Femoral Neck BMD			
Mean (SD)	0.790 (0.125)	0.708 (0.104)	
Lumbar Spine BMD			
Mean (SD)	0.930 (0.126)	0.846 (0.113)	
Normal	42 (67.7%)	76 (48.1%)	116 (52.7%)
Osteopenia	14 (22.6%)	74 (46.8%)	88 (40.0%)
Osteoporosis	4 (6.5%)	8 (5.1%)	12 (6.8%)
Severe Osteoporosis	2 (3.2%)	0 (0%)	2 (0.5%)
History of Fractures	9 (14.5%)	26 (16.5%)	35 (15.9%)
Family history of Fractures	9 (14.5%)	28 (17.7%)	37 (16.8%)

BMD decreased with age in both sexes at both the femoral neck and lumbar spine (**Figure 1**). Males consistently had higher BMD than females at all ages, with a slower rate of bone loss.

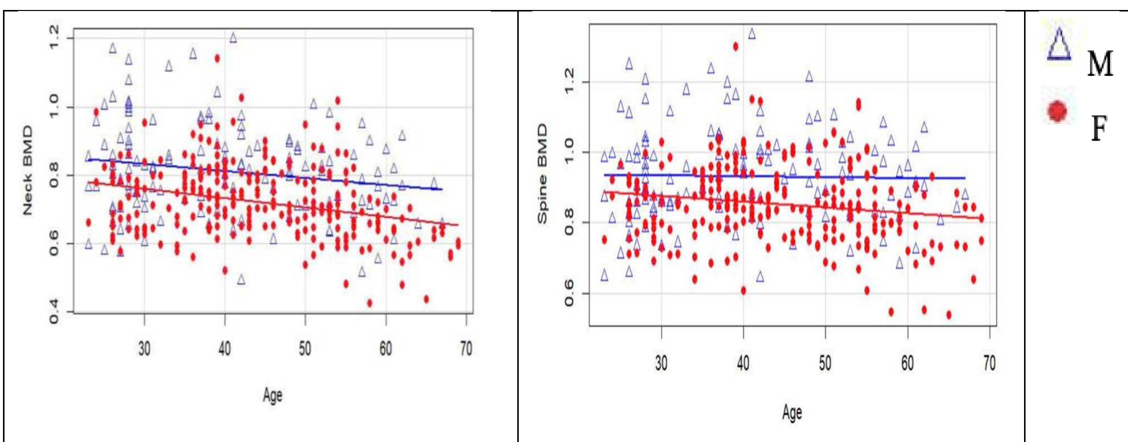

Figure 1. Trends of changes in femoral neck (left) and lumbar spine (right) BMD by age and sex

Most fracture cases (56/73, 77%) occurred before age 40, with the majority (89.3%) due to trauma. In fractures occurring after age 40, non-traumatic fractures were more common (11/23, 28.6%) (**Table 4**).

Table 4. Characteristics of Fractures by Sex, Cause, and Timing

	Male (N=24)	Female (N=49)	Total (N=73)
Time of fracture < 40	**20 (83.3%)**	**36 (73.5%)**	**56 (76.7%)**
Trauma	17 (85%)	33 (67.3%)	50 (89.3%)
Non-trauma	3 (15%)	3 (4.1%)	6 (10.7%)

	Male (N=24)	Female (N=49)	Total (N=73)
Time of fracture ≥ 40	**4 (16.7%)**	**13 (26.5%)**	**17 (23.3%)**
Trauma	3 (75%)	11 (84.6%)	14 (71.4%)
Non-trauma	1 (25%)	2 (15.4%)	3 (28.6%)

In the <40 age group, traumatic fractures primarily occurred at the clavicle, arm, forearm, wrist, ankle, tibia, hand, foot, facial bones, and femoral shaft, while non-traumatic fractures were rare (10.7%) and typically affected the arm, forearm, ankle, or foot. In the ≥40 age group, traumatic fracture sites were similar, but non-traumatic fractures were more common at the femoral neck, lumbar spine, and wrist. No cases of pelvic, cervical, or thoracic spine fractures were reported (**Figure 2**).

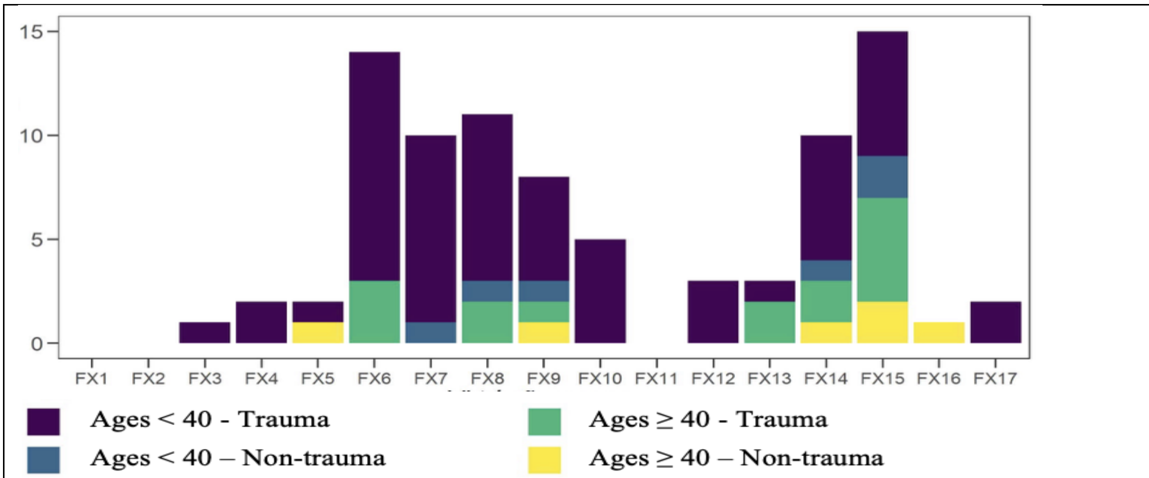

Figure 2. Distribution of Fractures by Location, Cause and Timing

Notes:

Fx1: Cervical vertebrae
Fx2: Thoracic vertebrae
Fx3: Zygomatic bone
Fx4: Ribs
Fx5: Femoral neck
Fx6: Clavicle
Fx7: Arm
Fx8: Forarm
Fx9: Wrist
Fx10: Hand
Fx11: Pelvis
Fx12: Femoral shaft
Fx13: Tibia
Fx14: Ankle
Fx15: Foot
Fx16: Lumbar vertebrae
Fx17: Elbow

Analysis of lifestyle and clinical characteristics in the poor bone health group (low BMD in young individuals, osteoporosis or severe osteoporosis in those ≥40, and non-traumatic fractures) identified key risk factors, including a family history of fractures, alcohol consumption, lack of calcium-vitamin D supplementation, and obesity (noted only in the non-traumatic fracture group) (**Table 5**).

Table 5. Lifestyle and clinical characteristics in the poor bone health group

Clinical characteristics	Low BMD (N=6)	Osteoporosis (N=14)	Non-trauma Fractures (N=11)
Family history of fractures (Yes)	**5/6 (83.3%)**	**10/14 (71.4%)**	**10/11 (91%)**
Co-morbidities (Yes)	0/6 (0%)	5/14 (35.7%)	3/11 (27.2%)

Drinking (Yes)	**5/6 (83.3%)**	**12/14 (85.7%)**	**9/11 (81.8)**
Smoking (Yes)	0/6 (0%)	1/14 (7.1%)	2/11 (18.1%)
Corticoid using (Yes)	0/6 (0%)	1/14 (7.1%)	0/11 (0%)
Calcium supplement (Yes)	**0/6 (0%)**	**3/14 (21.4%)**	**2/11 (18.1%)**
Vitamin D supplement (Yes)	**0/6 (0%)**	**2/14 (14.3%)**	**0/11 (0%)**
Milk drinking (Yes)	3/6 (50%)	7/14 (50%)	4/11 (36.3%)
Thin	2/6 (33.3%)	2/14 (14.3%)	1/11 (9.1%)
Overweight/obese	0/6 (0%)	4/14 (28.5%)	**8/11 (72.7%)**

Objective 2: Evaluation of the Association between BMD and Daily Physical Activity and Sedentary Time

The average total physical activity time was 532 minutes/week, with males being more active than females (708 vs. 444 minutes/week). Similarly, energy expenditure (MET-min/week) was significantly lower in females than males (1,920 vs. 3,280). Females also had lower participation in moderate-to-vigorous physical activity across all three domains (workplace, leisure, and transportation). Sedentary time was similar between sexes (6,710 minutes/week) and significantly exceeded physical activity time (**Table 6**).

Table 6. Physical Activity Characteristics

	Male (N=130)	**Female (N=261)**	**Total (N=391)**
Activity at work			
Vigorous activity	8 (6.2%)	7 (2.7%)	15 (3.8%)
Moderate activity	71 (54.6%)	89 (34.1%)	160 (40.9%)
Travel to and from places	61 (46.9%)	97 (37.2%)	158 (40.4%)
Recreational activities			
Vigorous activity	44 (33.8%)	35 (13.4%)	79 (20.2%)
Moderate activity	51 (39.2%)	113 (43.3%)	164 (41.9%)
Sedentary time (min/week)			
Mean (SD)	6560 (1000)	6790 (755)	6710 (850)
Physical activity time (min/week)			
Mean (SD)	708 (807)	444 (634)	532 (706)
Energy expenditure (MET-min/week)			
Mean (SD)	3280 (3660)	1920 (2690)	2370 (3110)
Meet WHO physical activity recommendations	104 (80%)	152 (58,2%)	256 (65,5%)

Analysis of physical activity by age and sex (**Figure 3**) showed that males under 40 had the highest energy expenditure (~4,000 MET-min/week), which decreased to ~3,000 MET-min/week in older age groups. Females maintained a consistent energy expenditure of ~3,500 MET-min/week across all ages.

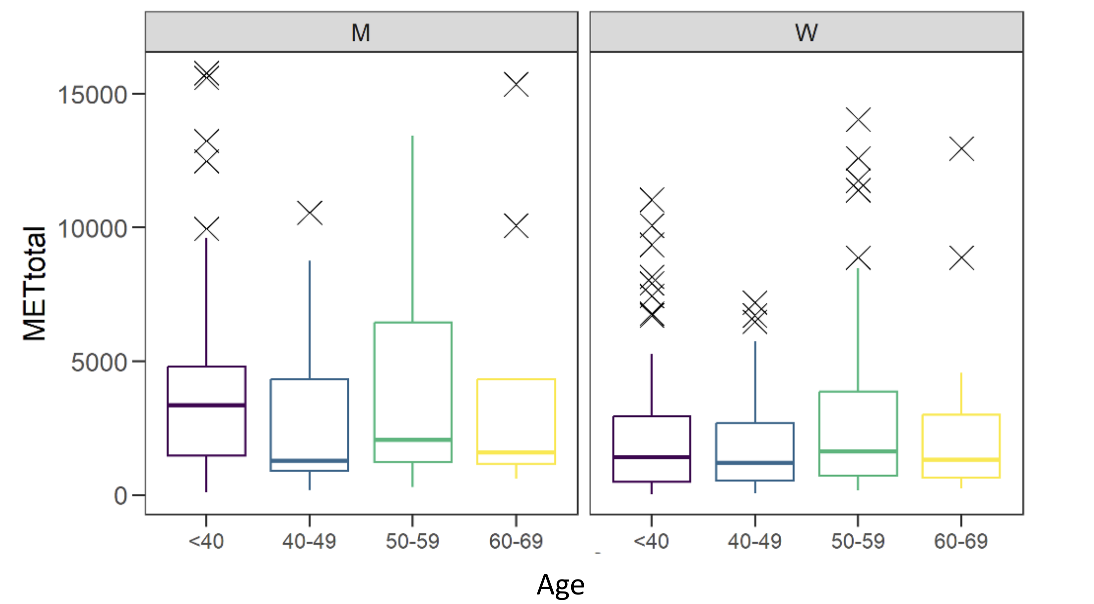

Figure 3. Characteristics of physical activity by age and sex

No statistically significant differences were found in physical activity time, energy expenditure, or sedentary time across BMD or age groups (**Table 7**).

Table 7. Differences in physical/sedentary activity by bone health status and age

	Physical activity time (min/week)	P value	Sedentary time (min/week)	P value	Energy expenditure (MET-min/week)	P value
Male < 40		**0.244**		**0.052**		**0.333**
Normal	739 (758)		6568 (805)		3677 (3460)	
Mildly low BMD	520 (558)		6885 (719)		2466 (2839)	
Low BMD	1152 (1611)		5708 (1704)		4670 (6464)	
Male ≥ **40**		**0.613**		**0.394**		**0.848**
Normal	737 (882)		6525 (1178)		3237 (3789)	
Osteopenia	568 (679)		6672 (965)		2723 (3804)	
Osteoporosis	918 (794)		6390 (796)		3696 (3222)	
Severe Osteoporosis	1200 (1273)		5310 (1570)		4800 (5091)	
Female < 40		**0.445**		**0.686**		**0.398**
Normal	427 (612)		6634 (700)		1855 (2559)	
Mildly low BMD	350 (552)		6746 (701)		1491 (2235)	
Low BMD	16.7 (28.9)		6843 (300)		66.7 (115)	
Female ≥ **40**		**0.977**		**0.805**		**0.937**
Normal	471 (676)		6846 (743)		1987 (2697)	
Osteopenia	483 (657)		6904 (822)		2156 (3030)	
Osteoporosis	522 (688)		6736 (937)		2092 (2765)	

However, linear regression analysis revealed a statistically and clinically significant positive association between physical activity time, energy expenditure, and BMD at the femoral neck and lumbar spine in the overall population (p<0.05). Sedentary time showed no significant association (p>0.05) in the general population but exhibited a negative trend, suggesting the need for further research with a larger sample. A positive association between energy expenditure and lumbar spine BMD was also found in overweight/obese females <40 years, but the regression coefficient (β=0.0000206) was too low to be clinically significant (**Table 8**).

Table 8. Associations between BMD and physical activity/sedentary time and energy expenditure by sex, age and BMI

	Femoral neck BMD		Lumbar spine BMD	
	Regression Coefficient	**P value**	**Regression Coefficient**	**P value**
Total				
Sedentary time	-0.09871412	0.051	-0.08809027	0.081
Physical activity time	**0.1190775**	**0.018**	**0.1063798**	**0.035**
Energy expenditure	**0.1534482**	**0.002**	**0.1392642**	**0.005**
Male < 40				
Thin				
Sedentary time	0.0000834	0.657	0.0003224	0.089
Physical activity time	-0.0000779	0.051	0.0001076	0.573
Energy expenditure	-0.0000219	0.494	0.0000236	0.626
Overweight/obese				
Sedentary time	-0.00000989	0.802	0.0000125	0.729
Physical activity time	-0.00000941	0.859	0.00000608	0.901
Energy expenditure	0.00000296	0.809	0.00000672	0.551
Male ≥ 40				
Thin				
Sedentary time	-0.000004	NA	-0.0002285	NA
Physical activity time	0.000002	NA	0.0001142	NA
Energy expenditure	0.000000507	NA	0.0000285	NA
Overweight/obese				
Sedentary time	0.0000463	0.056	0.0000295	0.291
Physical activity time	-0.0000649	0.064	-0.0000333	0.345
Energy expenditure	-0.0000129	0.051	-0.00000664	0.411
Female< 40				
Thin				
Sedentary time	-0.0000675	0.422	-0.0000543	0.559
Physical activity time	0.000174	0.098	0.0000915	0.452
Energy expenditure	0.0000409	0.101	0.0000212	0.459
Overweight/obese				
Sedentary time	-0.0000495	0.055	-0.0000568	0.055
Physical activity time	0.0000627	0.086	0.0000836	0.072
Energy expenditure	0.0000142	0.106	**0.0000206**	**0.036**
Female ≥ 40				
Thin				
Sedentary time	-0.0000467	0.679	-0.0000295	0.874
Physical activity time	0.0000733	0.641	0.0000675	0.795
Energy expenditure	0.0000183	0.641	0.0000168	0.795
Overweight/obese				
Sedentary time	-0.0000166	0.371	-0.0000172	0.512
Physical activity time	0.00000954	0.646	0.00000845	0.773
Energy expenditure	0.00000254	0.626	0.00000227	0.758

4. DISCUSSION

This study, conducted on 391 PNTU staff, aimed to assess BMD and its association with daily physical activity and sedentary time. The study population differed from the Ho Chi Minh City community in the VOS study [16], with a lower average age (40 for males, 44 for females vs. 50 and 51 in VOS). Male BMI was higher than female BMI (24.6 vs. 22.7) and significantly higher than in VOS (24.6 vs. 23.3). The prevalence of overweight and obesity was also higher, particularly in males (31.6% and 39.2% vs. 25.4% and 3% in VOS). Smoking rates in males were lower than in VOS (21.5% vs. 41.2%), but alcohol consumption was higher (46.2% vs. 44%), while females consumed significantly less alcohol (5.4% vs. 32.7%). These differences may reflect the office environment, which reduces harmful habits but increases obesity risk due to low physical activity.

Regarding nutrition, 45% of participants regularly consumed milk, but the average intake of 1.3 liters/week fell short of the recommended >2 liters/week. Gynecological characteristics in females (average age at menarche: 13.8 years, menopause: 51 years, pregnancies: 2) were consistent with VOS [17]. The prevalence of 1–2 non-communicable chronic diseases was 15.3%, with no cases of ≥3 conditions. Common diseases included type 2 diabetes (1.5%), hypertension (14%), osteoarthritis (6.9%), asthma (2.3%), and cancer (1.8%). Compared to VOS and Vietnamese community data for those ≥30 years (16), the prevalence of these conditions was significantly lower (diabetes: 9.7%, hypertension: 20%, knee osteoarthritis on X-ray: 34%), indicating good overall health among PNTU staff.

Females were more likely to use medications affecting bone health, with over 20% using contraceptives or hormone replacement therapy, 21.5% taking calcium, 17% using vitamin D, and only 3.1% reporting glucocorticoid use. Contraceptive use was much higher than in VOS (3.5%) [17], possibly due to past family planning policies for public servants. Despite Vietnam's tropical climate, vitamin D deficiency remains common (46% in females, 20% in males) [18], and the 17% vitamin D supplementation rate is low relative to recommended needs. Calcium supplementation was also inadequate compared to a study of Can Tho pharmacy students (21.5% vs. 33.8%) [19], raising questions about health information access among medical staff. Glucocorticoid use was appropriate for treating chronic respiratory conditions, with no evidence of misuse, though glucocorticoid abuse for musculoskeletal, dermatological, or respiratory symptoms remains common in Vietnam, posing risks for osteoporosis and fractures [20].

Compared to the VOS community population [21], BMD at the femoral neck was higher in PNTU staff for both sexes, while lumbar spine BMD was lower. This difference may be due to the younger average age and age limit of 69 years in this study, compared to 81 years in VOS. Calcification and osteophytes, common in those >40 years, may artificially inflate lumbar spine BMD in older groups [22].

Most participants had normal BMD, especially those <40 years (71%). BMD decreased with age in both sexes, with males consistently showing higher BMD and slower bone loss, consistent with the literature. However, in the ≥40 age group, while osteopenia was more prevalent in females (46.8% vs. 22.6%), males had a higher osteoporosis rate (9.7% vs. 5.1%). In the <40 age group, low BMD was more common in males (4.4% vs. 2.9%), contrary to the literature, which typically reports a higher osteoporosis risk in females. Better BMD maintenance in females may be due to the medical profession's heightened awareness of bone health and better dietary practices.

Male bone health may be affected by higher rates of risk factors like alcohol consumption and obesity.

Fractures are a key indicator of bone health, classified as traumatic (e.g., traffic accidents, high-impact forces, falls from heights greater than body length) or non-traumatic. Most fractures in this study occurred before age 40 (77%), primarily due to trauma (89%), with females having a higher fracture rate than males. Consistent with prior studies, fractures in young adults (ages 20–30) typically occur at the wrist, ankle, hand, or foot due to sports or recreational injuries, while femoral shaft, tibia, arm, rib, or facial fractures are often due to traffic accidents [23]. Fracture patterns also varied by sex, with females more likely to fracture the forearm [24].

In the ≥40 age group, fractures were less common (23%), but non-traumatic fractures were more frequent (28.6%). Non-traumatic fractures, often linked to low BMD and osteoporosis, typically occurred at the femoral neck, lumbar spine, or wrist, usually due to low-height falls. Differences in bone structure (macro- and micro-level), geometry, mineralization, lifestyle, comorbidities, and fall risk may explain variations in fracture characteristics by age and sex [25, 26].

Notably, only one case of non-traumatic lumbar spine fracture was recorded in the ≥40 age group, despite vertebral fractures being the most common osteoporotic fracture type in the literature [27]. This discrepancy may be due to reliance on participant self-reporting, which may miss asymptomatic vertebral fractures. A Ho Chi Minh City study reported a 12.2% prevalence of asymptomatic vertebral fractures in the community, with only about one-third detected clinically [28, 29].

The study identified factors associated with low BMD in young individuals, osteoporosis, and non-traumatic fractures, including a family history of fractures, alcohol consumption, lack of calcium-vitamin D supplementation, and obesity. These findings align with prior studies. No significant role was found for traditional risk factors like smoking, corticosteroid use, or low body weight, possibly due to their low prevalence in this medically knowledgeable population.

The study found no significant difference in sedentary time between males and females. However, males had higher participation in moderate-to-vigorous physical activity at work (6.2% vs. 2.7%) and during leisure (33.8% vs. 13.4%). Females also had lower transportation-related activity (37% vs. 47%), resulting in significantly lower energy expenditure (1,920 vs. 3,280 MET-min/week). Sedentary time was approximately 6,710 minutes/week in both sexes, far exceeding physical activity time. The highest physical activity levels were observed in males <40 years, consistent with prior studies on office workers' activity patterns.

No statistically significant differences were found in physical activity or sedentary time across BMD or age groups. However, linear regression analysis revealed a significant positive association between physical activity time, energy expenditure, and BMD at the femoral neck and lumbar spine in the overall population. No significant associations were found in subgroups by sex, age, or BMI.

These findings align with prior studies showing a positive association between occupational physical activity and BMD, particularly for high-impact activities like brisk walking, running, or resistance training [30, 31]. Epidemiological studies have also demonstrated the importance of physical activity in maintaining bone mass and muscle strength through osteoblast stimulation [32]. However, some studies have reported low BMD in males with high occupational activity [33] or no association between physical activity and BMD [34, 35]. These discrepancies may stem from differences in population characteristics, measurement methods, study design, confounders, or activity types.

Regarding sedentary behavior, PNTU staff spent over 70% of their waking hours in sedentary activities, but no association was found with BMD or non-traumatic fractures. This aligns with some prior studies [34, 35] but contrasts with recent research suggesting a negative impact of sedentary behavior on BMD [30]. A meta-analysis also reported inconsistent associations between sedentary behavior and BMD [36].

Despite using standardized DXA measurements and the GPAQ tool, the study found no significant impact of sedentary behavior on BMD. High physical activity levels in the study population may have mitigated the negative effects of sedentary time. Additionally, the study collected data on other risk factors (e.g., family history, alcohol consumption, calcium-vitamin D deficiency), which also influenced BMD. Long-term studies may better clarify the impact of physical activity on bone health [33].

The study has several strengths, including the use of standardized measurement methods for key variables. BMD was measured using Hologic DXA at standard sites (femoral neck and lumbar spine), and physical activity and sedentary time were assessed using GPAQ. The study also comprehensively collected data on other risk factors affecting bone health, enabling a thorough analysis.

However, the study has several limitations. First, the absence of a control group from a population with different occupational characteristics (e.g., manual laborers) may limit the ability to assess the impact of occupational activities, particularly sedentary behavior, on bone health. The study may be affected by sampling bias due to uneven participation rates between males and females, stemming from the gender imbalance in the target population and a higher refusal rate among males. Measurement errors may also arise from the use of self-reported questionnaires, which rely on participants' memory. To minimize errors, analyses were conducted separately for males and females, and estimations of physical activity, sedentary time, and energy expenditure were rigorously applied according to WHO GPAQ guidelines.

Second, the cross-sectional design of the study does not allow for a comprehensive evaluation of the causal relationship between occupational activities and bone health in office workers. Changes in BMD may occur over an extended period, and a longitudinal study could provide more accurate results regarding the long-term impact of physical activity.

Finally, the study population consisted of PNTU staff, a group closely associated with the healthcare sector. This may result in unique lifestyle and health awareness characteristics, making the study results not fully representative of the broader office worker population.

5. CONCLUSION

The study provided important insights into the BMD of PNTU staff and related factors. The results recorded osteoporosis and low BMD prevalence rates of 6.8% and 3.5%, respectively, and identified a positive association between physical activity and BMD. The low osteoporosis prevalence compared to some previous studies suggests relatively good bone health in the study population, possibly due to the heightened awareness of osteoporosis prevention among healthcare workers. However, the low rates of calcium and vitamin D supplementation, with the relatively high prevalence of alcohol consumption, highlight the need for additional interventions alongside increased physical activity. to effectively prevent osteoporosis. Furthermore, long-term studies are needed to comprehensively evaluate the bone health status of healthcare workers.

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