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Clinical Issues

Work- and Travel-related Physical Activity and Alcohol Consumption: Relationship With Bone Mineral Density and Calcaneal Quantitative Ultrasonometry

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Abstract

A number of healthy workers rarely exercise because of a lack of time or resources. Physical activity related to work and everyday travel may be more feasible, but evidence of its beneficial effect on bone health is scarce. We assessed if this form of physical activity was associated with higher bone mineral density (BMD) and stiffness index (SI) when adjusted for recreational physical activity, age, body mass index, smoking, alcohol consumption, education, and serum level of 25-hydroxyvitamin D. Healthy workers, aged 25−54 yr, of the Electricity Generating Authority of Thailand were surveyed. The outcomes were BMD (lumbar spine, femoral neck, and total hip) and calcaneal SI. Physical activity was estimated using the global physical activity questionnaire and considered active when >600 metabolic equivalent tasks (min). Of 2268 subjects, 74% were men. Active male subjects had significantly higher BMD at the femoral neck and total hip ($p < 0.005$). However, the association was not significant with male lumbar spine BMD, male SI, or any bone parameters in women ($p > 0.05$). In men, work and travel physical activity seems beneficial to male bone health; hence, it should be encouraged. Furthermore, smoking appeared harmful while moderate alcohol consumption was beneficial.

Key Words: Alcohol consumption; bone mineral density; global physical activity questionnaire; physical activity; quantitative ultrasonometry.

Introduction

Given the large elderly population in Asia *(1)*, osteoporosis will be a major health problem in the coming years and the healthcare cost has already been a concern *(2)*. Epidemiological studies have reported significant associations between sedentary lifestyles and risk of osteoporotic fracture *(3)*, as well as between physical activity and higher bone mineral density (BMD) *(4−7)* or higher quantitative ultrasonometry (QUS) measurements *(8,9)*.

Physical activity, according to the World Health Organization-developed questionnaire called the Global Physical Activity Questionnaire (GPAQ) *(10,11)*, involves 3 domains: recreation, work, and travel. Most studies on physical activity *(4−9)* have focused on recreational physical activity or impact exercise, which many working people may find it difficult to regularly engage because of inaccessibility to such facilities or lack of time *(12)*, leading to poorer bone

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health *(13)*. It is not clear whether a moderate level of physical activity related to routine work and travel is associated with better bone health in terms of BMD or QUS.

We aimed at assessing if physical activity, at least at a moderate level, in the domain of work together with the domain of travel (i.e., work and travel physical activity) was associated with better bone strength parameters, using dual X-ray absorptiometry (DXA) at the lumbar spine and the hip, as well as using QUS at the calcaneus.

Materials and Methods

The Ethics Committee of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University, approved the study protocol. Written informed consent was obtained from all subjects.

Subjects

The study was part of the baseline health survey of the third cohort of employees, aged 25–54 yr, of the Electricity Generating Authority of Thailand *(14)*. All subjects fasted overnight; blood samples were then taken early in the morning for blood chemistry analysis, including serum level of 25-hydroxyvitamin D (i.e., 25(OH)D2 and 25(OH)D3). Each subject then completed a self-administered questionnaire, which included questions on demographic data, education level (bachelor degree: yes/no), past and present illnesses, current medication, smoking (current: yes/no), alcohol (ever/never) and milk consumption (at least 1 glass/day: yes/no), physical activity, and menopause status (women only).

In addition, they underwent a physical examination, BMD determination at the lumbar spine and hip, and QUS of the calcaneus. Their body weight and height were measured in light clothing without shoes and body mass index (BMI) was calculated as body weight (kg)/squared height (m^2). Subjects with conditions or medication known to affect bone health were excluded.

Physical Activity

Physical activity was assessed using version 2 of the GPAQ *(10,11)*, which quantified physical activity in a typical week in 3 different domains: work, travel, and recreation. Physical activity in the travel domain was classified as moderate intensity (this domain was not considered vigorous) if the subject pedaled or walked 10 min continuously. For the work and recreation domains, physical activity that caused large increases in breathing or heart rate (like lifting heavy loads, running, or playing football) was considered vigorous. The physical activity causing small increases in breathing or heart rate (such as brisk walking, carrying light loads, cycling, or swimming) was considered moderate. The number of metabolic equivalent tasks (MET) used in the calculation for moderate and vigorous activity was 4 and 8, respectively. For each domain, the product of time spent (min) and the designated number of MET were calculated. Because it was the aim of this study to assess physical activity in the domains of work and travel together, the sum of their MET-min was used as a single parameter (i.e., work and travel physical activity), while that in the recreation domain was analyzed as a separate type of physical activity. For a given category (work and travel or recreation), subjects were considered active when they had a moderate level of physical activity ($\geq$600 MET-min/wk) in that particular category.

Bone Mineral Density

The testing method has been described in an earlier report *(15)*. Each subject changed into light clothing before undergoing BMD assessment by DXA at the lumbar spine (L1–L4 vertebrae) and hip (femoral neck and total hip). All measurement procedures were performed according to the International Society for Clinical Densitometry (ISCD) recommendations *(16)* by ISCD-certified technologists using a Hologic QDR 4500 DXA scanner (Hologic, Inc., Bedford, MA). Quality assurance procedures using a spine phantom were performed daily. The BMD root mean square coefficients of variation were 0.82% and 1.51% for the lumbar spine and total hip, respectively.

Quantitative Ultrasonometry

Using a Lunar Achilles ultrasound machine, the stiffness index (SI) *(17)* at the calcaneus was determined in all subjects. Quality assurance procedures were performed daily before the commencement of SI measurement to ensure acceptable precision error of less than 1.5%.

Serum Vitamin D Measurement

Serum 25(OH)D2 and 25(OH)D3 were analyzed by liquid chromatography–tandem mass spectrometry with an Agilent 1200 Infinity liquid chromatograph (Agilent Technologies, Santa Clara, CA) coupled to a QTRAP® 5500 tandem mass spectrometer (AB SCIEX, Foster City, CA and using a MassChrom® 25-OH-Vitamin D3/D2 diagnostics kit (Chromsystems, Munich, Germany). Vitamin D was the summation of serum 25(OH)D2 and 25(OH)D3 (inter-assay and intra-assay coefficients were 6.3% and 5.0%, respectively).

Statistical Analysis

Male and female data were analyzed separately. Continuous data were expressed as mean ± SD or median (range) where appropriate. Categorical data were expressed as count (%).

A linear regression was performed to assess the association between work and travel physical activity and each of the dependent bone variables, that is, BMD at the lumbar spine, femoral neck, and total hip and calcaneal SI. Covariates whose roles have previously been established in bone health (i.e., age, BMI, alcohol use, smoking, total serum vitamin D level, milk consumption, and menopausal status) were simultaneously included in the linear regression model. Education was only included when p value in the univariate analysis was less than 0.2. Normality of residual of regression model was checked using Shapiro–Wilk test and quantile or normal distribution plot. A p value of less than 0.05 was considered statistically significant. All analyses were performed using Stata 12 statistical software (StataCorp, College Station, TX).

Results

Of the 2326 subjects (90% of the total cohort) who completed the DXA scan to measure BMD, 58 subjects (16 men) were excluded because of rheumatoid arthritis in 7, systemic lupus erythematosus in 2, thyroid disease in 4, oophorectomy in 25, L-thyroxine treatment in 16, and sex hormone treatment in 4. Finally, there were 2268 subjects (87.8% of the total cohort; 1681 men). Of these, 1897 subjects (73.4% of the total cohort; 1400 men) also underwent QUS.

The majority of subjects (74.1%) were male because of the demographic proportion of Electricity Generating Authority of Thailand employees (Table 1). Most subjects had a bachelor's degree, were alcohol users and non-smokers, and did not regularly engage in any physical activity. As compared with their female subjects, men were heavier, taller, and had more tendency to be smokers and alcohol users as well as to have higher vitamin D level. They had higher femoral neck and total hip BMD, but not lumbar spine BMD or SI. Active physical activity in the domain of work and travel and that of recreation were found in 725 (43%) and 384 (23%) men and 172 (29%) and 83 (14%) women, respectively.

Table 1
Clinical Characteristics of the Study Population

Characteristics (n = 2268)	Male (n = 1681)	Female (n = 587)
Continuous data		
Age (years)	40.6 ± 7.2	39.6 ± 6.6
Body weight (kg)	70.5 ± 11.1	55.4 ± 9.3
Height (cm)	169.3 ± 5.9	158.0 ± 5.5
BMI (kg/m^2)	24.6 ± 3.5	22.2 ± 3.6
Vitamin D (ng/ml)[a]	26.1 ± 6.1	21.4 ± 6.2
Lumbar BMD (g/cm^2)	0.977 ± 0.120	0.973 ± 0.112
Femoral neck BMD (g/cm^2)	0.821 ± 0.121	0.750 ± 0.105
Total hip BMD (g/cm^2)	0.949 ± 0.127	0.861 ± 0.111
Stiffness index[a] (%)	101.9 ± 17.9	102.0 ± 16.2
Categorical data		
Regular milk consumer, subjects (%)	159 (9.5)	71 (12.1)
Current smoker, subjects (%)	373 (22.2)	20 (3.4)
Alcohol user, subjects (%)	1205 (71.7)	197 (33.9)
PA ≥ 600 MET-min/wk, subjects (%)		
Recreation	384 (22.8)	83 (14.4)
Work and travel	718 (42.7)	172 (29.3)
Bachelor level, subjects (%)	1138 (67.7)	527 (89.8)
Menopause, subjects (%)		9 (1.5)

Abbr: BMD, bone mineral density; BMI, body mass index; MET, metabolic equivalent; PA, physical activity.

[a] n = 1897 (1400 men, 497 women).

Multiple regression analysis (Table 2) revealed that the femoral neck and total hip BMD of active men in the work and travel physical activity were significantly higher than inactive men. Their femoral neck and total hip BMD was 0.016 g/cm^2 (95% confidence interval: 0.006−0.027) and 0.019 g/cm^2 (95% confidence interval: 0.007− 0.030) higher, respectively. The mean lumbar spine BMD of active men was 0.011 g/cm^2 higher, but the difference was not statistically significant ($p = 0.055$). Also, the difference was not significant for SI in men or any bone parameters in women.

Unsurprisingly, recreational physical activity was significantly associated with SI and BMD at all 3 sites in both men and women ($p < 0.05$). As compared with inactive subjects, active men and women had significantly higher BMD by 0.015−0.225 and 0.027−0.045 g/cm^2 as well as higher SI by 4.5% and 5.1%, respectively.

Age was negatively associated with BMD and SI, except female lumbar spine BMD and female SI (Table 2), while BMI was positively associated with BMD at all 3 sites in both genders. Of note, alcohol use was associated with higher BMD at all 3 sites in men ($p < 0.05$) but not in women. However, it was not associated with higher SI in any gender.

Other Covariates

Smoking was significantly associated with lower lumbar spine BMD and lower SI in men. This was not evident in women. Total serum vitamin D level was significantly associated with male SI but not female SI of BMD at any sites. Milk consumption and menopausal status (women only) were not associated with any of the bone parameters. Among the models with education, that is, male SI and male lumbar spine, male femoral neck, and female total hip BMD (Table 3), only male SI was statistically significant.

Discussion

Physical Activity

The World Health Organization GPAQ has been tested in male and female adults of diverse sociocultural, educational, and economic backgrounds in many countries; the results indicate acceptable reliability and validity for monitoring physical activity in a population health survey *(18−20)*. According to the GPAQ analysis guide, 600 MET-min/wk or more to classify physical activity was considered active *(10)*; hence, we used it as a cutoff point.

Our study is the first to use GPAQ to assess the association of work and travel physical activity with BMD and SI. Most studies performed in either young or elderly individuals *(21)*. The beneficial effect of work and travel physical activity on BMD was demonstrated in men at the femoral neck and total hip after adjusting for age, BMI, smoking, alcohol use, recreational physical activity, vitamin D, milk consumption,

Table 2
Multiple Regression Analysis of Physical Activity and Bone Status in Healthy Workers

	Lumbar spine BMD				Femoral neck BMD				Total hip BMD				SI			
	Beta	Coef.	95% CI	*p* value	Beta	Coef.	95% CI	*p* value	Beta	Coef.	95% CI	*p* value	Beta	Coef.	95% CI	*p* value
Male																
Recreation[a]	0.06	0.015	0.002, 0.029	0.024	0.08	0.022	0.009, 0.034	<0.001	0.06	0.018	0.005, 0.031	0.008	0.11	4.47	2.28, 6.66	<0.001
Work and travel[a]	0.05	0.011	−0.000, 0.023	0.055	0.07	0.016	0.006, −0.027	0.003	0.08	0.019	0.007, −0.030	0.001	0.03	1.15	−0.78, 3.07	0.243
Age	−0.09	−0.001	−0.002, −0.001	0.001	−0.24	−0.004	−0.005, −0.003	<0.001	−0.16	−0.003	−0.003, −0.002	<0.001	−0.24	−0.62	−0.76, −0.48	<0.001
BMI	0.19	0.006	0.004, −0.008	<0.001	0.38	0.012	0.011, −0.014	<0.001	0.39	0.014	0.012, −0.015	<0.001	−0.02	−0.12	−0.39, 0.15	0.377
Alcohol user	0.05	0.013	0.000, −0.026	0.047	0.06	0.016	0.004, −0.028	0.007	0.07	0.020	0.007, −0.032	0.002	0.02	0.94	−1.15, 3.02	0.378
Smoker	−0.05	−0.015	−0.029, −0.001	0.032	0.00	0.001	−0.011, 0.014	0.862	−0.01	−0.002	−0.016, 0.011	0.745	−0.07	−2.78	−4.99, −0.57	0.014
Vitamin D	0.03	0.000	−0.000, 0.001	0.307	0.03	0.001	−0.000, 0.001	0.226	0.03	0.001	−0.000, 0.002	0.144	0.07	0.18	0.03, −0.33	0.020
Milk	−0.03	−0.011	−0.030, 0.009	0.291	0.00	−0.001	−0.019, 0.017	0.905	−0.03	−0.014	−0.034, 0.005	0.145	0.00	−0.18	−3.61, 3.26	0.919
Bachelor level	0.05	0.012	−0.001, 0.025	0.083	0.01	0.001	−0.010, 0.013	0.828	ni				0.08	2.70	0.65, −4.75	0.010
			Adjusted R^2	0.050			Adjusted R^2	0.206			Adjusted R^2	0.186			Adjusted R^2	0.086
			p value	<0.001			*p* value	<0.001			*p* value	<0.001			*p* value	<0.001
Female																
Recreation[a]	0.12	0.040	0.013, −0.067	0.003	0.09	0.027	0.004, −0.049	0.021	0.14	0.045	0.020, −0.070	<0.001	0.11	5.05	0.67, −9.43	0.024
Work and travel[a]	−0.06	−0.015	−0.035, 0.006	0.158	−0.03	−0.007	−0.024, 0.010	0.430	−0.04	−0.010	−0.028, 0.009	0.321	−0.03	1.00	−4.19, 2.19	0.538
Age	−0.09	−0.002	−0.003, −0.000	0.052	−0.12	−0.002	−0.003, −0.001	0.004	−0.06	−0.001	−0.002, 0.000	0.169	−0.13	−0.30	−0.54, −0.07	0.012
BMI	0.31	0.009	0.007, −0.012	<0.001	0.45	0.012	0.009, −0.014	<0.001	0.46	0.014	0.012, −0.016	<0.001	0.04	0.15	−0.26, 0.57	0.468
Alcohol user	−0.01	−0.003	−0.022, 0.017	0.803	−0.01	−0.002	−0.019, 0.015	0.787	0.02	0.005	−0.014, 0.023	0.615	0.06	1.88	−1.28, 5.03	0.242
Smoker	0.03	0.017	−0.034, 0.068	0.513	0.06	0.031	−0.011, 0.074	0.146	0.01	0.004	−0.043, 0.051	0.875	0.06	5.04	−2.92, 13.0	0.214
Vitamin D	−0.01	0.000	−0.002, 0.001	0.875	0.01	0.000	−0.001, 0.001	0.781	0.01	0.000	−0.001, 0.002	0.832	−0.05	−0.11	−0.33, 0.12	0.349
Milk	0.02	0.006	−0.022, 0.034	0.671	−0.03	−0.010	−0.033, 0.014	0.427	−0.04	−0.012	−0.038, 0.014	0.372	0.05	2.43	−1.95, 6.81	0.276
Bachelor level	ni				Ni				−0.03	−0.011	−0.040, 0.018	0.445	ni			
Menopause	−0.03	−0.023	−0.098, −0.052	0.552	−0.03	−0.021	−0.083, 0.042	0.519	−0.01	−0.009	−0.079 to 0.061	0.806	−0.04	5.22	−17.7, 7.23	0.410
			Adjusted R^2	0.091			Adjusted R^2	0.189			Adjusted R^2	0.211			Adjusted R^2	0.028
			p value	<0.001			*p* value	<0.001			*p* value	<0.001			*p* value	0.013

Abbr: BMD, bone mineral density; BMI, body mass index; CI, confidence interval; coef., correlation coefficient; MET, metabolic equivalent; ni, not included in model; SI, calcaneal stiffness index.

[a] Physical activity ≥600 MET-min/wk.

Table 3
Univariate Analysis of Work and Travel Physical Activity As Well As Bachelor Degree and the Dependent Variables (BMD and SI)

	Lumbar spine BMD			Femoral neck BMD			Total hip BMD			SI		
Categorical data	Mean	SD	*p* value	Mean	SD	*p* value	Mean	SD	*p* value	Mean	SD	*p* value
Male												
Work and travel[a]												
No	0.973	0.122		0.814	0.122		0.943	0.129		101.7	17.5	
Yes	0.982	0.118	0.129	0.829	0.119	0.012	0.960	0.125	0.006	102.3	18.3	0.541
Bachelor level												
No	0.967	0.119		0.814	0.111		0.949	0.118		99.1	16.8	
Yes	0.977	0.120	0.019	0.824	0.121	0.113	0.950	0.132	0.936	103.6	18.3	<0.0001
Female												
Work and travel[a]												
No	0.977	0.114		0.750	0.104		0.862	0.114		102.2	16.5	
Yes	0.964	0.106	0.207	0.748	0.106	0.839	0.860	0.105	0.836	101.3	15.6	0.538
Bachelor level												
No	0.968	0.098		0.762	0.102		0.883	0.105		101.0	18.4	
Yes	0.973	0.113	0.743	0.749	0.105	0.353	0.859	0.112	0.112	102.1	16.0	0.656

Abbr: BMD, bone mineral density; MET, metabolic equivalent; SD, standard deviation; SI, calcaneal stiffness index.
[a] Weekly physical activity $\geq$ 600 MET-min.

and education. The magnitudes of effect were similar to that of recreational physical activity with a beta coefficient of 0.07 vs 0.08 and 0.08 vs 0.06 at the femoral neck and total hip, respectively (Table 2). The results may be applicable to male office workers in general and warrant promoting physical activity of this type among them. These activities, which cause small increases in breathing or heart rate, include brisk walking, pedaling a bicycle, or carrying light loads. Such activities do not require much extra time or resources and are easy to incorporate into daily routines of working adults.

However, the effect was not evident in women. Many studies showed no association between general physical activity in young adulthood and bone mass *(21)*. In addition to hormonal differences *(22)*, gender also influences the bone mass phenotype via genetic expression *(23)*. Boys' bones are more sensitive to physical loading than girls' *(24,25)*, suggesting that this gender difference exists since childhood. The response to physical activity among women could vary because of differences in physical activity type *(26)*, intensity *(27)*, volume *(28)*, frequency *(29)*, subject age *(30)*, menopausal status *(31)*, and body part involved. Moreover, it could be explained by lower participation rate in women (Table 1). Additionally, the effect of moderate physical activity on female bones may be small that requires a larger sample size to demonstrate. A statistically significant difference may be detected at a higher cutoff point, but it will not answer the question of association of bone health with moderate physical activity. In both men and women, physical activity in the recreation domain was independently and positively correlated with SI and BMD at all 3 sites, consistent with many previous studies *(4–9)*.

Alcohol Consumption

Alcohol consumption, when heavy, is harmful to many organs including bones *(32)*, but when moderate, is associated with better BMD *(32,33)* and QUS parameters, which could be explained by a U- or J-shaped relationship *(34,35)*. Such associations were significant in our study among male users for BMD at all 3 sites. Besides initial suppressive effect on bone resorption mediated by glucagon-like peptide-2, the mechanisms by which BMD is increased include acute inhibition of bone *(36)*, direct inhibition of estrogen catabolism, and promotion of bone formation by silicon and polyphenols, which is present at high levels in beer and red wine, respectively *(37)*.

Although a positive association between circulating estrogen concentrations and alcohol intake has been shown in postmenopausal women *(37,38)*, such association was not consistent in premenopausal women *(39–41)*. The lack of association between alcohol intake and BMD or SI in women in our study could be explained by a small number of postmenopausal women.

Other Covariates

Consistent with biological basis *(42)*, our results did show negative association between smoking and lumbar spine BMD as well as SI in men. The lack of association between bone health parameters and milk consumption was because milk consumption represented only part of the dietary calcium.

SI

The advantages of SI over BMD lie in its similar ability to predict fracture *(43)* while having more accessibility and portability but lack of radiation. Our results did not demonstrate its association with work and travel physical activity despite significant association with recreational physical activity in both genders (Table 3). However, our models could explain only 8.6% and 2.8% of the variation in SI in men and women, respectively. QUS parameters were reported to have modest or poor correlation with DXA *(9)*. The discrepancies between the SI and BMD results could be explained by the fact that, in addition to BMD and bone mass, QUS indices also reflect the bone quality (bone microarchitecture and strength) *(43)*. The ISCD does not recommend its use other than screening because of the lack of universal cutoff value and its limited precision *(44)*. The studies that reported association between QUS parameters and physical activity were performed with either vigorous physical activities, such as sports *(45)* or army training *(9)*, or in wider age range than ours *(8)*, allowing more variation in QUS parameters; hence, more chance to detect correlation.

Limitations

The low adjusted R^2 values of the models could be explained by the presence of unmeasured confounding variables and the use of categorical variables rather than continuous ones. Moreover, the study design was cross-sectional; therefore, only associations were established.

Physical activity in our study was not categorized as aerobic exercise vs weight resistance, but rather work and travel vs recreation. This was because we aimed to study physical activity that working people could readily incorporate into their daily routine. Because of the nature of the measurement, based on using a questionnaire rather than an actual measurement of physical activity, there may be recall bias in the quantification of physical activity. Also, we did not use sedentary leisure as a covariate; however, it does not preclude meeting physical activity recommendations *(46)*.

Alcohol consumption variable was categorized into user and non-user, precluding quantitative information. The user group may include heavy users, in whom association with BMD has been shown to be negative *(32)*. As a result, positive associations between alcohol use and BMD at all 3 sites in men in our study were unlikely to be overestimated.

Because of time and budget constraint, we were able to scan 87.8% and 73.4% of the subjects in the cohort, respectively. Nevertheless, the subjects included in this study are similar to the total cohort in terms of age, BMI, proportions of male, smokers, alcohol users, and physically active workers *(14)* and should be representative.

In conclusion, we demonstrated that moderate physical activity in the domain of work and travel was independently associated with higher BMD at the femoral neck and total hip in male workers. Furthermore, in men, low to moderate alcohol use was independently associated with higher BMD at all 3 sites, while smoking was independently associated with lower BMD at the lumbar spine.

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