European Review for Medical and Pharmacological Sciences 2023; 27: 5822-5830

Correlation between physical activity, nutritional intake, and osteoporosis in postmenopausal women: a preliminary evaluation

C. CERULLI[1], E. MORETTI[1], A. PARISI[1], E. TRANCHITA[1], M. DI LAURO[2], C. MINGANTI[1], M.A. PERRONE[3], A. MURRI[1], F. GRECO[1,4], G. MARRONE[2], A. NOCE[2], E. GRAZIOLI[1,4]

[1]Department of Movement, Human and Health Sciences, University of Rome "Foro Italico", Rome, Italy
[2]Department of Systems Medicine, University of Rome Tor Vergata, UOC of Internal Medicine - Center of Hypertension and Nephrology Unit, Rome, Italy
[3]Department of Cardiology and University Sports Centre, University of Rome Tor Vergata, Rome, Italy
[4]Department of Experimental and Clinical Medicine, "Magna Graecia" University, Catanzaro, Italy

G. Marrone, A. Noce and E. Grazioli equally contributed to this work.

Abstract. – OBJECTIVE: Osteoporosis is a chronic metabolic syndrome associated with debilitating consequences that represents one of the major non-communicable diseases and the most common bone illness that affects both men and women. This observational study evaluates the amount of physical activity and the nutritional intake in a group of postmenopausal women who have a sedentary job.

PATIENTS AND METHODS: All subjects underwent a medical evaluation, a body impedance analysis to evaluate body composition (fat mass, fat-free mass, and body cell mass), and a dual-energy X-ray absorptiometry to analyze bone mineral density. Additionally, a 3-day food record questionnaire and the International Physical Activity Questionnaire were administered respectively to evaluate patients' foods and beverages assumptions and the participants' Physical Activity levels.

RESULTS: The study showed that most of the patients had a moderate activity level and inadequate calcium and vitamin D assumption compared to guidelines.

CONCLUSIONS: The onset of osteoporosis seemed to be reduced at higher levels of leisure time, domestic, and transport activities, even in subjects who have a sedentary job and insufficient assumption of micronutrients.

Key Words:
Osteoporosis, Diet, Physical activity, Menopause.

Introduction

Osteoporosis is a pathological chronic condition characterized by three main aspects: low bone mass or bone mineral density (BMD), deterioration of bone micro-architecture, and increased risk of fracture[1]. According to the World Health Organization (WHO) criteria, osteoporosis is defined as a BMD that lies 2.5 standard deviations (SD) or more below the average value for young, healthy people (a T-score of <-2.5 SD)[2]. According to this definition[2], osteoporosis affects approximately 6.3% of men over the age of 50 and 21.2% of women of the same age range, globally. Therefore, considering the entire world population, approximately 500 million people worldwide may be affected by osteoporosis. Across Europe (European Union, plus Switzerland and the United Kingdom) in 2019, 32 million individuals aged >50 were estimated to have osteoporosis, equivalent to 5.6% of the total European population aged >50, or approximately 25.5 million women (22.1% of women aged >50) and 6.5 million men (6.6% of men aged >50)[3]. Bones are characterized by active tissue that is constantly resorbed and rebuilt by osteoclasts and osteoblasts, respectively. The balance between these two actions is essential for maintaining adequate mineral homeostasis and a suitable bone density. Osteoporosis is caused by an impaired tissue balance, unbalanced to resorption rather than reconstruction[4]. Many factors can influence bone homeostasis: these are classified as modifiable and not modifiable. For example, age, female gender, family history of osteoporosis, previous fracture, ethnicity, estrogenic deficiency and amenorrhea, menopause, and hysterectomy are considered not modifiable risk factors. Whereas alcohol assumption, smoking, low body mass index (BMI), physical inactivity, poor nutrition, and eating disorders represent modifiable risk factors.

Corresponding Author: E. Tranchita, MD; e-mail: eliana.tranchita@gmail.com

Physical Exercise (PE) is an important prevention strategy, throughout life, able to counteract the risk of osteoporosis. Particularly, PE might be one of the most promising low-cost non-pharmacological interventions to protect bone health, inducing improvement in the bone turnover of osteopenic and osteoporotic subjects[5,6]. Although the specific mechanisms of exercise in bone health are still controversial, it is clear that PE induces mechanical loadings maintaining the bone formation and resorption balance[7,8]. When PE is individualized with optimal loads and duration, it can induce an osteogenic effect that stimulates the mechano-transduction process in bone tissue[9]. Specifically, by the regulation of signals for osteoblasts and osteoclasts, osteocytes respond to mechanical load, leading to bone anabolic effects. As result, stressed bone cells increase bone formation activity and maintain the proper bone mass and density[7,8]. In the literature was shown how a sedentary lifestyle may increase the risk of cardiovascular disease, metabolic disorder, cancer, and on osteoporosis onset. Although sedentary behavior itself is a risk factor for many diseases, the clinical practice focuses mostly on increasing Physical Activity (PA) levels, with less emphasis on reducing sedentary lifestyles[10]. Thus, it is important to understand how sedentary work can contribute to osteoporosis onset.

The Role of Nutrition in Osteoporosis

A balanced diet represents a preventive strategy for osteoporosis. In particular, vitamin D, protein, calcium, phosphorus, and magnesium play a pivotal role in the mechanisms of bones' reabsorption/deposition. Moreover, an adequate protein intake is important, representing a crucial element in the structural matrix of bone tissue.

Firstly, the study aims to evaluate how participants' nutritional intake differs from the current guidelines for osteoporosis prevention. The second outcome is to understand if the amount of PA they practiced is sufficient to counteract the effect of sedentary work on osteoporosis onset.

Patients and Methods

This is a retrospective observational study. An awareness campaign on the risk of osteoporosis was promoted in our University of Rome "Foro Italico" for menopausal employed women. The women were invited to undergo a screening visit. Participants who met the following inclusion criteria were enrolled: 1) aged between 50-65 years old, 2) postmenopausal stage, 3) doing a sedentary job 4) asymptomatic for osteoarticular pain. Exclusion criteria were: 1) use of pharmacological therapy for osteoporosis, 2) unwillingness to undergo screening tests and questionnaires. From a total population of 56 menopausal employed women, 42 agreed to undergo the examination. 12 women did not meet the inclusion criteria because they were on drug treatment for osteoporosis (bisphosphonate, vitamin D, and/or calcium supplement). After the first evaluation, 30 women were enrolled, the epidemiological features are shown in Table I.

The selected population underwent a specific screening at the Laboratory of Physical Exercise and Sport Sciences at the University of Rome "Foro Italico". The research protocol was submitted to the Department Institutional Board of our University, which, due to the observational nature of the protocol, verified that all the procedures agreed with the ethical standards of the Helsinki Declaration (Protocol Number CAR 106/2021). Moreover, all subjects were verbally and in written form informed about the procedures of the study, and they signed the written informed consent. All patients underwent a medical examination

Table I. Patients features.

Patients (n=30)	Mean	SD
Age (years)	60.58	8.43
6-Minutes Walking Test (m)	617.83	54.17
IPAQ Scoring (MET)	1351.97	100.35
Calcium (mg/day)	320.93	295.63
Phosphorus (mg/day)	878.99	321.78
Vitamin D (µg/day)	2.35	2.93
Calcium/Phosphorus ratio	0.36	0.29
Weight (kg)	61.93	8.31
Height (cm)	163.10	5.23
BMI (kg/m^2)	24.37	3.34
FFM (%)	70.38	5.70
FM (%)	29.62	5.70
BMC (%)	35.25	3.60
BMD L1_L4 (g/cm^2)	1.11	0.11
L1_L4 T-score	-0.57	0.88
L1_L4 Z-score	0.80	0.88
BMD Femur (g/cm^2)	0.88	0.10
Femur T-score	-1.02	0.80
Femur Z-score	-0.28	0.73
BMD Femoral Neck (g/cm^2)	0.85	0.10
Femoral Neck T-score	-1.08	0.87
Femoral Neck Z-score	-0.04	0.80

BMC, body cell mass; BMD, bone mass density; BMI, body mass index; FFM, free fat mass; FM, fat mass; IPAQ, international physical activity questionnaire; MET, metabolic equivalent od task; SD, standard deviation.

carried out by a specialist in Sports Medicine to exclude possible cardiovascular disease. Anamnesis and the electrocardiogram at rest (Standard 12-lead ECG) were done by the specialist using EDAN SE-1515® device with the subject in the supine position and recorded with a paper speed of 25 mm/s and at a standard gain of 1 mV/cm.

Body Composition Assessment

Anthropometric parameters were detected, body weight (kg) was measured to the nearest 0.01 kg using a balance scale (Seca 711, Hamburg, Germany). Height (m) was measured using a stadiometer to the nearest 0.1 cm (Seca 220, Hamburg, Germany). BMI was calculated as body weight divided by height squared (kg/m^2). To evaluate the body composition, subjects underwent bioelectrical impedance analysis (BIA). Body composition was assessed *via* a portable multifrequency digital bioelectrical impedance device (Handy 3000®; DS Medica, Milano, Italy). Through this device, all measured values and collected data were stored and promptly recovered. Recorded values of total body analysis are expressed as absolute and percentages value. Fat mass (FM) percentage, fat-free mass (FFM) percentage, and body cell mass (BCM) were considered for the analysis. Before the bioelectrical impedance analysis, patients were instructed to be well hydrated (water only), be fasted for 4 hours, avoid PA for 12 hours, to abstain from diuretics and alcohol for 48 hours.

Bone mineral density (BMD) was detected by dual-energy X-ray absorptiometry (DEXA), which uses computer software to determine the bone density of the hip (neck of the femur) or lumbar spine. BMD was evaluated through Lunar DPX-DXA® System Software version: 16 [SP 2] GE Medical Systems Lunar.

Functional Evaluation

The sport Specialist administered the 6-Minute Walking Test (6MWT). This test provides information regarding functional capacity; it consists in walking for 6 minutes at the higher possible speed, measuring the performance distance, and evaluating the walking endurance[11]. During the test, the heart rate was monitored by a heart rate monitor. At the end of the test, the perceived exertion was evaluated through the Borg CR10 scale.

Questionnaires

Participants underwent two questionnaires: International Physical Activity Questionnaire (IPAQ) and a 3-day food record.

PA levels of participants were assessed using the IPAQ short questionnaire. IPAQ assesses PA in different domains, including a) leisure-time PA, b) domestic and gardening activities, c) work-related PA, and d) transport-related PA, in adult subjects aged 18-65 years[12]. This questionnaire considers three specific types of activity: walking, moderate-intensity, and vigorous-intensity activities. Data collected with IPAQ can be reported as a continuous measure. The volume of PA performed during the week, and analyzed by IPAQ, can be calculated by considering the energy demand defined in metabolic activity equivalents (METs). METs are multiples of the resting metabolic rate, and a MET-minute is calculated by multiplying the MET score by the minutes performed of activity. MET-minute scores are equivalent to kilocalories for a 60-kilogram person. Kilocalories may be computed from MET-minutes using the following equation: MET-min x (weight in kg/60 kg). The calculated IPAQ score has demonstrated reliability and validity; higher scores represent greater levels of activity[12,13]. Subjects were classified as "high level" of PA if they were engaged in 1,500-3,000 MET minutes a week of activities; "moderate level" if they were engaged in at least 600-1,500 MET minutes a week of activities; "low level" if they are engaged in less than 600 MET minute a week of activities[13].

The 3-day food record questionnaire monitors, over a specific period of 3 days, the foods and beverage consumption of the participants[14]. It is validated and provides reliable estimates of the intake of almost all nutrients. The 3-day food record was used to evaluate the mean assumption of vitamin D, calcium, and phosphorus of employed women recruited. To complete the questionnaire, participants were instructed to report both the quality and the quantity of food and beverage intake, to describe the size of the portion or its weight. Moreover, the assumption of supplementation or integration was recorded. The 3-day food record questionnaires were inserted into a digital program for bromatological study (WinFood®, Medimatica, Colonnella, Italy). Vitamin D, calcium, and phosphorus intakes were considered and were compared to European recommendations for nutritional intake suggested for osteoporosis prevention in postmenopausal women[15].

Statistical Analysis

The statistical package IBM SPSS version 21 (IBM Corp., Armonk, NY, USA) was used for the analysis. Data were reported as means±SD. Before the analysis, the Shapiro-Wilk test was applied to test the normal distribution of the data. Pearson correlation coefficient was used to evaluate the correlation between subjects' variables and BMD at both vertebral and femoral sites. Statistical significance was established as $p \leq 0.05$.

Results

This study analyzed a population of postmenopausal women with a mean 60.58±8.43 of age. As reported in Table I, they showed a normal BMI (mean value 24.37±3.34 kg/m^2) an FM value of 19.66±6.03 kg with a moderate excess in FM% of 29.62±5.70% (the normal value for women is 14-24%), while the FFM showed a value of 45.3±4.6 kg (70.3±5.7%) and the BMC a value of 22.8±3.1 kg (35.2±3.6%), which are in line with the normal data of the task.

In the lumbar district (L1-L4), 21 subjects showed a normal value of BMD, and 9 osteopenia; in the femoral district and femoral neck, 17 participants had normal BMD values, 11 osteopenia, and 2 osteoporosis.

IPAQ scores demonstrated that most of the subjects had moderate activity levels with a median score of 1,351.97±100.35 MET-min/week. 2 women showed low activity levels (<700 MET-min/week), and showed high activity levels with a score >2,520 MET-min/week.

The 3-day food record administration reported the average intake of important micronutrients for BMD such as calcium, phosphorus, and vitamin D (Table II). The consumption of calcium was not enough to guarantee good values of BMD. Only phosphorus intake was in line with the dietary recommendation of European guidelines. The calcium/phosphorus ratio average was 0.36±0.29 mg, evidencing an insufficient value below the guidelines. Lastly, in our sample, the dietary assumption of vitamin D was inadequate.

A positive correlation was shown between phosphorus intake and femoral BMD, femoral T-score, and femoral Z-score ($p<0.05$), as reported in Table III. A similar positive correlation was found between phosphorus intake and BMD, T-score, and Z-score of the femoral neck ($p<0.01$). According to the functional tests, no relation between fitness level, analyzed through the 6MWT, and the stage of osteoporosis was found, although the mean value of the test (617.83±54.17 m) is in line with the normal value (400-700 m in subjects <70 years old). A direct correlation was found between FFM and the 6MWT, and an inverse correlation was observed between BMI and 6MWT, as well as between FM and 6MWT, highlighting that a higher BMI and FM could reduce the capacity to walk for 6 minutes (Table III). In our study population, no significant correlation between PA levels and BMD scores was found. Moreover, no correlation was found between body composition values (FM, FFM, BMC) and BMD of all sites evaluated (femoral and L1-L4). Finally, there was no correlation between the FFM values and the osteoporosis stage.

Discussion

The postmenopausal years seem to be one of the most challenging periods for women. It is observed during this period an increased risk of chronic diseases, such as type 2 diabetes mellitus, coronary heart disease, and osteoporotic fractures, particularly in sedentary women [16,17]. Moreover, this population usually decreases PA levels and does not follow a proper diet to counteract the negative effects of menopause, such as sarcopenia and osteoporosis[18,19].

The strength of this study is the relationship considered between PA, sedentary work, and the onset of osteoporosis in menopausal women. In this retrospective observational study, a group of 30 postmenopausal women underwent a specific screening in order to evaluate if the amount of PA and nutritional intake can influence osteoporosis condition. All the recruited women did a sedentary job and were asymptomatic for osteoarticular pain. The anthropometric parameters,

Table II. Values of micronutrients assumed.

	N	Mean	SD	Recommended intake
Calcium (mg/day)	30	320.9	295.6	800-1,000
Phosphorus (mg/ day)	30	879.0	321.8	700
Vitamin D (μg/ day)	30	2.4	2.9	10
Femoral Neck Z-score	-0.04	0.80		

N, number; SD, standard deviation.

Table III. Pearson's correlation coefficients between all parameters were evaluated.

Patients (n=30)	Age (years)	IPAQ (MET)	6MWT	Ca (mg/day)	P (mg/day)	Vit D (µg/day)	Ca/P	BMI (kg/m²)	FFM (%)	FM (%)	BMC (%)	BMD L1_L4	L1_L4 Tscore	L1 L4 Zscore	BMD Femur	Femur Tscore	Femur Zscore	BMD F Neck	F Neck Tscore	F Neck Zscore
Age (years)																				
IPAQ (MET)	.423*																			
6MWT	-.252	-.45																		
Ca (mg/day)	-.324	-.315	.192																	
P (mg/day)	.011	.007	-.142	.778**																
Vit D (µg/day)	-.189	-.099	-.287	.216	.165															
Ca/P	-.346	-.374*	.272	.891**	.136	.115														
BMI (kg/m²)	.616**	.589**	-.332	,031	-.109	-.370*	-.370*													
FFM (%)	-.495**	-.207	.111	-,067	.268	,132	0,132	-.812**												
FM (%)	.495**	.207	-.111	,067	-.268	-,132	-0,1318424	.812**	-1,000**											
BMC (%)	-.261	-.046	.0640	-,061	.398	,109	.108	-.445*	.751**	-.751**										
BMD L1_L4	.389*	.226	.020	-.235	.031	-.137	-.257	0,086	-,022	.022	.030									
L1_L4 Tscore	.371	.215	.023	-.227	.034	-.114	-.248	0,066	,003	-.003	.057	.998**								
L1 L4 Zscore	.333	.058	.017	-.274	-.070	-.018	-.263	-0,121	,208	-.208	.0.20	.897**	.909**							
BMD Femur	.351	.192	-.253	.120	.576*	-.121	-.068	0,369	-.409*	.409*	-.196	.452*	.439*	.265						
Femur Tscore	.353	.192	-.231	.118	.562*	-.140	-.064	0,365	-.407*	.407*	-.189	.459*	.446*	.272	.999**					
Femur Zscore	.305	.037	-.246	.086	.542*	-.045	-.083	0,188	-,219	.219	-.050	.397*	,394	.380	.935**	.934**				
BMD F Neck	.285	.156	-.318	.030	.651**	-.131	-.199	0,339	-.374*	.374*	-.133	.428*	.418*	.268	.907**	.904**	.829**			
F Neck Tscore	.286	.158	-.317	.025	.649**	-.135	-.204	0,342	-.374*	.374*	-.134	.421*	.411*	.259	.908**	.905**	.829**	1.000**		
F Neck Zscore	.266	.051	-.341	-.009	.624**	-.064	-.227	0,198	-.219	.219	-.013	.375*	.374*	.372*	.837**	.834**	.887**	.937**	.935**	

BMC, body cell mass; BMD, bone mass density; BMI, body mass index; F, femoral; FFM, free fat mass; FM, fat mass; MET, metabolic equivalent; 6MWT, 6-minute walking test; Vit, Vitamin; *$p \leq 0.05$; **$p \leq 0.01$.

body composition, and BMD were collected and correlated to PA levels. PA was measured through both the IPAQ questionnaire and 6MWT. Moreover, the same parameters were compared with the nutritional habits of participants. Although it is difficult to accurately measure PA levels in the adult population, IPAQ and other similar questionnaires are validated in literature for this use[20]. IPAQ scores showed that most of the participants had moderate PA levels, and only 2 women had insufficient PA levels. These results were confirmed by the 6MWT that showed normal values for all participants. The amount of PA measured may probably prevent an advanced degree of osteoporosis in these women. Over the years, studies investigated the positive effect of PE on osteoporosis, trying to identify the most effective type[1,21-24]. For many years, aerobic training was the main protocol suggested to osteoporosis patients, however, some aerobics activities (e.g., regular walking, swimming, cycling) seem to produce a low level of strain on bones and maybe not be enough to induce skeletal adaptation[9]. Nowadays, the recommendations for osteoporosis patients suggest combining aerobic training and resistance and balance training[25]. Most clinical guidelines of osteoporosis consider PE (e.g., weight-bearing activities, progressive resistance exercise and/or power training, balance, and mobility training) a therapy in osteoporosis management and prevention of fracture[6,11-16]. The weight-bearing component during exercise is represented by gravitational activities at high impact, and with endurance mechanical components[6]. Exercises such as jumping and running or any other exercise in which arms, feet, and legs are bearing weight, seem to be the most effective in causing bone stress and subsequent mechano-transduction leading to an increase in BMD[6,8]. However, weight-bearing exercise, to be safe and well-tailored, should consider individual bone health conditions, especially for those people with severe osteoporosis, a recent history of fracture, or other comorbidities. Particularly, the dose and type of PE need to be preceded by a specific patient evaluation, and it needs to be supervised by a Sport Specialist[22,26,27].

Nutritional habits were investigated through a 3-day food record, and all the contents of the questionnaires were evaluated by a bromatological software, that gave the mean value of macro and micronutrients assumed by participants. Moreover, it showed that calcium assumption was not in line with international recommendations, while phosphorus assumption was in agreement with recommended nutrient intakes of European guideline[13]. The calcium/phosphorus ratio showed an insufficient value in comparison to the value of 1:1 suggested. Furthermore, the dietary assumption of vitamin D is also inadequate. European guidelines suggest 800-1,000 mg of calcium and 800 IU (10 μg) of vitamin D per day in men and women over the age of 50 years[13]. Recent studies carried out on older men and on postmenopausal women, advise that supplementation of calcium alone may not be enough to reduce fracture risk. This suggests that additional vitamin D supplementation is required because it is important in Calcium metabolism. 80-90% of vitamin D comes from cutaneous synthesis thanks to sunlight exposure, the remaining 10-20% derives from diet, particularly from food like oily fish and mushrooms. The rate of bone turnover increases when the serum level of 25-Hydroxyvitamin D is lower than 50 nmol/l having an unfavorable effect on bone tissue in postmenopausal women and in elderly[28]. In addition, 4,000-5,000 IU of vitamin D per day seems to be important also to have a good performance and to maintain a good level of strength[35]. Regarding phosphorus, it is important to underline that an excessive dietary intake of phosphorus, induces an imbalance in the calcium-phosphorus relation, altering the endocrine regulation of calcium homeostasis. This disequilibrium is detrimental to bone health, because there are regulatory hormones [e.g., fibroblast growth factor-23 (FGF-23), parathormone PTH] that respond to dietary phosphorus intake. It is important to underline that both FGF-23 and PTH influence the renal synthesis and circulating levels of calcitriol (that is, the active form of vitamin D), but they work in a reverse manner: FGF-23 inhibits, while PTH stimulates the calcitriol synthesis[29].

Most of the women presented a normal value of T-score and Z-score both in the lumbar and in the femoral district, even if their nutritional habits were not in line with recommendations to guarantee good values of BMD. A direct correlation was shown between Phosphorus intake and both femoral neck and whole femoral BMD, however, calcium and vitamin D assumptions were under the recommended value. This is one of the modifiable risk factors on which it is possible to work. Suggesting an adequate amount of micronutrient intake represents the first step for an effective preventive osteoporosis strategy. The right amount of calcium in a balanced ratio with phosphorus can help to prevent secondary hyperparathyroidism, bone resorption, and fragile bones. At the same time, the increased assumption of vitamin D can help to modulate calcium metabolism and to improve BMD[28].

Moreover, a direct relationship was found between FFM (%) and the 6MWT, confirming that greater FFM allows patients to walk a longer distance in 6 minutes. Having a valid muscle mass is a prerequisite to obtain an adequate stimulus on bone tissue and preventing osteoporosis[9]. At the same time, a valid muscle mass can reduce the risk of falls, which represents one of the goals of PE therapy in osteoporosis. Therefore, strength and/or power PE in a multi-component program may be useful to achieve an optimal osteogenic effect of exercise and to prevent falls[30]. Daly et al[9] suggest that bones respond better to dynamic intermittent rather than static loads when they are high in magnitude and applied rapidly, when they are applied in unusual or different loading directions or patterns. Moreover, if an adequate load intensity is achieved, bone tissue needs relatively few loading cycles (repetitions) to increase BMD. According to several studies, to reach bone adaptation, an optimal exercise should stress, properly, the minimum effective strain (MES), which is the "set-point" represented by the typical loads encountered during everyday activities[8,9]. Indeed, following the principle of progressive overload, the exercise should exceed the strain of everyday activities, and it should progressively increase to induce osteogenic stimulus[8]. In a multi-component exercise program, the intensity recommended for weight-bearing is moderate to vigorous, with a gradual increase of ground reaction forces (GRF)[6,31]. Marching on the spot (GRF=1.7 times body weight), then stepping exercise at a speed of 120-125 bpm using a 15-cm-high bench (GRF=1.8 times), and lastly, heel-drops performed on a hard surface (GRF=2.7 times) may represent a low-intensity progression of weight-bearing exercise for bone health in sedentary elderly patients[6]. The high-intensity exercises, such as heel drops, are recommended in the last part of the training progression for patients at low risk of fracture[31]. The multi-modal exercise training also involves strength and/or power training. Particularly, lower limb and spinal extensor exercises are important in fall prevention training[26]. Moreover, to increase BMD, strength training should be progressively increased over time, reaching mechanical load around 80% to 85% of one repetition maximum (1-RM)[23]. Current guidelines suggest performing strength exercises at 70% of 1-RM, or at least at moderate intensity, to complete 2-3 sets of 8-12 repetitions[32]. Power training represents another component of exercise able to induce high strain rates on the bone[30]. The specific characteristic of fast concentric muscle contractions may decrease the atrophy of type II fast-twitch muscle fibers, which are related to the loss in osteoporotic patients[33]. To understand how exercise intervention can be effective in bone protection, it is necessary to consider the responsiveness of bone to loading. The typical bone remodeling cycle is slow and lasts from 3 to 8 months[34,35]. Thus, a supervised exercise program should last at least 6-9 months, but it is ideally from 12 to 24 months with a frequency ≥2 sessions a week[9,24].

Limitations

This observational study has some limitations: firstly, it represents a preliminary evaluation, and due to the small number of subjects, the results may not be definitive and need to be confirmed by studies on larger samples. Furthermore, the 3 days food record and IPAQ questionnaires may appear limited in reliability, measurement error, and responsiveness, but they represent a simple tool validated in scientific literature to collect data regarding nutrient intake and PA in the general population.

Conclusions

In our study, we analyzed the amount of PA, nutritional intake, and BMD in a group of 30 women involved in sedentary jobs with a median age of 60 years old. The activities practiced in leisure time, domestic activities, and transport (moderate and vigorous intensity) practiced by participants were analyzed to observe if they are enough to guarantee a reduced onset of osteoporosis. Moreover, even if the mean value of dietary calcium intake was insufficient, the phosphorus intake was in line with the recommendation allowing a good BMD in our sample. Therefore, the post-menopause years might be the time when women can benefit more from PE and a balanced diet to contrast the negative effects of aging. Therefore, it is a priority to introduce specific PE protocols and nutritional recommendations in the healthcare paths of postmenopausal women.

Furthermore, nowadays, very little is known about the impact of occupation during working life and osteoporosis. There is probably not a linear association between PA and fracture risk, but it will be important to understand how sedentary work can favor the onset of osteoporosis and how to counteract this mechanism.

Authors' Contributions

Conceptualization, A.P. and A.N.; methodology, C.C.; Software, E.T.; formal analysis, C.M.; resources, F.G. and M.D.L.; data curation, E.M.; writing-original draft preparation, E.T., and A.M.; writing-review and editing, A.P. and E.G.; supervision, A.N., E.G., and M.A.P. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Ethics Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Department Institutional Board of University of Rome "Foro Italico" which, due to the observational nature of the protocol, verified that all the procedures were in agreement with the ethical standards of the Helsinki Declaration (Protocol Number CAR 106/2021).

Informed Consent

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

ORCID ID

Claudia Cerulli: 0000-0003-2637-7968
Elisa Moretti: 0009-0000-0417-0822
Attilio Parisi: 0000-0003-2648-8406
Eliana Tranchita: 0000-0001-9613-8124
Manuela Di Lauro: 0000-0001-8118-1330
Carlo Minganti: 0000-0002-1975-8415
Marco Alfonso Perrone: 0000-0002-0511-2621
Arianna Murri: 0000-0003-4642-6317
Francesca Greco: 0000-0002-6539-7796
Giulia Marrone: 0000-0002-5854-2086
Annalisa Noce: 0000-0003-1310-3730
Elisa Grazioli: 0000-0003-4245-1320

References

1) Murri A, Moretti E, Tranchita E, Cerulli C, Santilli A, Parisi A, Grazioli E. The effectiveness of home-based physical activity on osteoporosis: a narrative review of possible intervention. Med Sport 2021; 74: 509-527.
2) World Health Organization. Assessment of Fracture Risk and Its Application to Screening for Postmenopausal Osteoporosis. World 1994; 843: 1-129
3) Kanis JA, Norton N, Harvey NC, Jacobson T, Johansson H, Lorentzon M, McCloskey EV, Willers C, Borgström F. SCOPE 2021: a new scorecard for osteoporosis in Europe. Arch Osteoporos 2021; 2: 82.
4) Rondanelli M, Faliva MA, Barrile GC, Cavioni A, Mansueto F, Mazzola G, Oberto L, Patelli Z, Pirola M, Tartara A, Riva A, Petrangolini G, Peroni G. Nutrition, Physical Activity, and Dietary Supplementation to Prevent Bone Mineral Density Loss: A Food Pyramid. Nutrients 2021; 14: 74.
5) Shojaa M, Von Stengel S, Schoene D, Kohl M, Barone G, Bragonzoni L, Dallolio L, Marini S, Murphy MH, Stephenson A, Mänty M, Julin M, Risto T, Kemmler W. Effect of Exercise Training on Bone Mineral Density in Post-menopausal Women: A Systematic Review and Meta-Analysis of Intervention Studies. Front Physiol 2020; 23: 652.
6) Benedetti MG, Furlini G, Zati A, Letizia Mauro G. The Effectiveness of Physical Exercise on Bone Density in Osteoporotic Patients. Biomed Res Int 2018; 23: 484-531.
7) Maycas M, Esbrit P, Gortázar AR. Molecular mechanisms in bone mechanotransduction. Histol Histopathol 2017; 32: 751-760.
8) Frost HM. Bone's mechanostat: a 2003 update. Anat Rec A Discov Mol Cell Evol Biol 2003; 275: 1081-1101.
9) Daly RM, Dalla Via J, Duckham RL, Fraser SF, Helge EW. Exercise for the prevention of osteoporosis in postmenopausal women: an evidence-based guide to the optimal prescription. Braz J Phys Ther 2019; 23: 170-180.
10) Park JH, Moon JH, Kim HJ, Kong MH, Oh YH. Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. Korean J Fam Med 2020; 41: 365-373.
11) Balke B. A simple field test for the assessment of physical fitness. Rep 63-6. Rep Civ Aeromed Res Inst US 1963; 53: 1-8.
12) Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF, Oja P. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 2003; 35: 1381-1395.
13) Guidelines for the data processing and analysis of the International Physical Activity Questionnaire". Available at: www.ipaq.ki.se
14) Yang YJ, Kim MK, Hwang SH, Ahn Y, Shim JE, Kim DH. Relative validities of 3-day food records and the food frequency questionnaire. Nutr Res Pract 2010; 4: 142-148.
15) Kanis JA, Cooper C, Rizzoli R, Reginster JY; Scientific Advisory Board of the European Society for Clinical and Economic Aspects of Osteoporosis (ESCEO) and the Committees of Scientific Advisors and National Societies of the International Osteoporosis Foundation (IOF). European guidance for the diagnosis and management of oste-

oporosis in postmenopausal women. Osteoporos Int 2019; 30: 3-44.
16) Sowers MR, La Pietra MT. Menopause: its epidemiology and potential association with chronic diseases. Epidemiol Rev 1995; 17: 287-302.
17) Monteleone P, Mascagni G, Giannini A, Genazzani AR, Simoncini T. Symptoms of menopause - global prevalence, physiology and implications. Nat Rev Endocrinol 2018; 14: 199-215.
18) Nielsen BR, Abdulla J, Andersen HE, Schwarz P, Suetta C. Sarcopenia and osteoporosis in older people: a systematic review and meta-analysis. Eur Geriatr Med 2018; 9: 419-434.
19) Kirk B, Zanker J, Duque G. Osteosarcopenia: epidemiology, diagnosis, and treatment—facts and numbers. J Cachexia Sarcopenia Muscle 2020; 11: 609-618.
20) Suleiman S, Nelson M. Validation in London of a physical activity questionnaire for use in a study of postmenopausal osteopaenia. J Epidemiol Community Health 1997; 51: 365-372.
21) Todd JA, Robinson RJ. Osteoporosis and exercise. Postgrad Med J 2003; 79: 320-323.
22) Watson SL, Weeks BK, Weis LJ, Harding AT, Horan SA, Beck BR. High-Intensity Resistance and Impact Training Improves Bone Mineral Density and Physical Function in Postmenopausal Women With Osteopenia and Osteoporosis: The LIFTMOR Randomized Controlled Trial. J Bone Miner Res 2018; 33: 211-220.
23) Hong AR, Kim SW. Effects of Resistance Exercise on Bone Health. Endocrinol Metab (Seoul) 2018; 33: 435-444.
24) Zitzmann AL, Shojaa M, Kast S, Kohl M, von Stengel S, Borucki D, Gosch M, Jakob F, Kerschan-Schindl K, Kladny B, Lange U, Middeldorf S, Peters S, Schoene D, Sieber C, Thomasius F, Uder M, Kemmler W. The effect of different training frequency on bone mineral density in older adults. A comparative systematic review and meta-analysis. Bone 2022; 154: 116-230.
25) Giangregorio LM, Papaioannou A, Macintyre NJ, Ashe MC, Heinonen A, Shipp K, Wark J, McGill S, Keller H, Jain R, Laprade J, Cheung AM. Too Fit To Fracture: exercise recommendations for individuals with osteoporosis or osteoporotic vertebral fracture. Osteoporos Int 2014; 25: 821-835.
26) Giangregorio LM, McGill S, Wark JD, Laprade J, Heinonen A, Ashe MC, MacIntyre NJ, Cheung AM, Shipp K, Keller H, Jain R, Papaioannou A. Too Fit To Fracture: outcomes of a Delphi consensus process on physical activity and exercise recommendations for adults with osteoporosis with or without vertebral fractures. Osteoporos Int 2015; 26: 891-910.
27) Kemmler W, von Stengel S. Bone: High-intensity exercise to prevent fractures - risk or gain? Nat Rev Endocrinol 2018; 14: 6-8.
28) Rizzoli R, Bischoff-Ferrari H, Dawson-Hughes B, Weaver C. Nutrition and bone health in women after the menopause. Womens Health (Lond) 2014; 10: 599-608.
29) Calvo MS, Moshfegh AJ, Tucker KL. Assessing the health impact of phosphorus in the food supply: issues and considerations. Adv Nutr 2014; 5: 104-113.
30) von Stengel S, Kemmler W, Kalender WA, Engelke K, Lauber D. Differential effects of strength versus power training on bone mineral density in postmenopausal women: a 2-year longitudinal study. Br J Sports Med 2007; 41: 649-655.
31) Marques EA, Mota J, Machado L, Sousa F, Coelho M, Moreira P, Carvalho J. Multicomponent training program with weight-bearing exercises elicits favorable bone density, muscle strength, and balance adaptations in older women. Calcif Tissue Int 2011; 88: 117-129.
32) Zamoscinska M, Faber IR, Büsch D. Do Older Adults With Reduced Bone Mineral Density Benefit From Strength Training? A Critically Appraised Topic. J Sport Rehabil 2019 D; 29: 833-840.
33) Terracciano C, Celi M, Lecce D, Baldi J, Rastelli E, Lena E, Massa R, Tarantino U. Differential features of muscle fiber atrophy in osteoporosis and osteoarthritis. Osteoporos Int 2013; 24: 1095-1100.
34) Duckham RL, Frank AW, Johnston JD, Olszynski WP, Kontulainen SA. Monitoring time interval for pQCT-derived bone outcomes in postmenopausal women. Osteoporos Int 2013; 24: 1917-1922.
35) Weiss K, Devrim-Lanpir A, Jastrzębski Z, Nikolaidis PT, Hill L, Knechtle B. Performance improvement in sport through vitamin D–a narrative review. Eur Rev Med Pharmacol Sci 2022; 26: 7756-7770.