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Association between handgrip strength and maximum expiratory flow with site-specific bone mineral density of healthy young adults

Rimsha Tahir[1], Faateh Ahmad Rauf[2], Shafaq Ismail[3], Huma Saeed Khan[4], Shahid Hasan[5]

1-3 3rd Year MBBS Student, CMH Lahore Medical College and Institute of Dentistry, Lahore, Pakistan; **4,5** CMH Lahore Medical College and Institute of Dentistry, Lahore, Pakistan

Correspondence: Rimsha Tahir. **Email:** Rimsha895@live.com

Abstract

Objective: To explore the association of handgrip strength and peak expiratory flow rate with site-specific bone mineral density T scores, and to study the correlation of body mass index and physical activity with the three parameters.

Methods: The cross-sectional study was conducted in November 2018 at the Combined Military Hospital, Lahore Medical College and Institute of Dentistry, Lahore, Pakistan, and comprised healthy young adults. Data was collected using the international physical activity questionnaire. The subjects were grouped into low, moderate and high categories. Handgrip strength, peak expiratory flow rate, bone mineral density T scores and body mass index were measured for each subject. Data was analysed using SPSS 24.

Results: Of the 102 subjects, 52(50.9%) were males and 50(49%) were females. There was a significant difference between the median values for all parameters of males and females ($p<0.05$). Bone mineral density and physical activity were moderately associated with handgrip strength and peak expiratory flow rate

($p<0.05$). Body mass index showed a moderate association with bone mineral density ($p<0.05$).

Conclusion: Healthy young adults with better respiratory function and handgrip strength were found to have higher values of site-specific calcaneal bone mineral density. Subjects with higher reported levels of physical activity and a higher body mass index within a healthy range presented with improved values of bone mineral density, handgrip strength and peak expiratory flow rate.

Key Words: Bone mineral density, Handgrip strength, Peak expiratory flow rate, Body mass index, Physical activity.

Introduction

Poor bone health has important implications for individuals, their quality of life and the economics of a society. Presently in Pakistan, low bone health and osteoporosis is not regarded as a national health priority and there are no sufficient health policies on the matter. Bone mineral density (BMD) is used in clinical medicine as an indirect marker of osteoporosis and fracture risk. It is a medical term denoting the amount of mineral matter, or bone mineral content, per square centimetre of bone [1]. BMD results from a dynamic process of osteoclasts resorbing older bone and the periodical deposition of new matrix by osteoblasts, in a process known as remodelling that occurs throughout the lifetime. Bone resorption predominates in the elderly, with each standard deviation (SD) decrease in BMD being linked to 2.6 times increase of hip-fracture risk. Low bone mass is thus an important risk factor for fracture as well as osteoporosis, a condition characterised by skeletal fragility and a T score of <-2.5 [2].

Common risk factors for osteoporosis include a personal history of fracture, current low bone mass, advanced age, female gender, menopausal status, low lifetime calcium intake, vitamin D deficiency and an inactive lifestyle [3]. There are certain medical conditions from which secondary osteoporosis is known to stem from as well, including endocrine disorders, renal diseases, disorders of the gastrointestinal tract (GIT) as well as manifesting as an adverse effect of medications, like immunosuppressants, anti-seizure medications, corticosteroids etc. It has also been shown in a study that a low haemoglobin (Hb) value significantly affected bone turnover in the tested subjects and has shown to be an independent risk factor for osteoporosis [4]. Moreover, it is imperative to recognise the prevalence of osteoporosis in a first-degree relative as an essential clinical indication for BMD screening. It is important to identify certain pre-emptive measures regarding lifestyle changes, and hormone replacement therapy (HRT) may prove to be beneficial in reducing premenopausal bone loss.

Restricted lung function has also been detailed to producing an undesirable effect on BMD. The relationship between maximum expiratory flow with BMD can be understood by analysing the bone mass of patients with chronic obstructive pulmonary disease (COPD) presenting with a reduced peak expiratory flow rate (PEFR). Though the precise mechanism linking diminished lung function to osteoporosis remains unclear, United Kingdom National Institute for Health and Care Excellence (NICE) guidelines on osteoporosis recommend utilising it as a fracture prediction tool, considering COPD as a secondary cause of osteoporosis [5].

The current study was planned to explore the association of handgrip strength (HGS) and PEFR with site-specific BMD T scores, and to study the correlation of body mass index (BMI) and physical activity (PA) with the three parameters.

Subjects and Methods

The cross-sectional study was conducted in November 2018 at the Combined Military Hospital (CMH) Lahore Medical College and Institute of Dentistry, Lahore, Pakistan. After approval was obtained from the institutional ethics review committee, the sample size was calculated using the formula [6]:

$$\text{Sample size} = \frac{{(Z_{1-a/2})}^2 SD^2}{d^2}$$

In the formula, ${Z_{1-a/2}}^2$ = Is a standard normal variate and at $p<0.05$ it is 1.96; d = absolute error calculated via $d^2 = (\mu_1 - \mu_2)$ =19.27-19.07 = 0.04. The average SD of the variable is taken from a previous study [7]: Average SD^2= $\{\frac{0.94+0.74}{2}\}^2$ =0.7056

The sample was raised using non-probability convenience sampling and informed consent was taken from each subject. Those included were normal healthy male and female volunteers aged 18-25 years. The subjects were without a current status or any history of smoking, COPD, fractured bones, anaemia, consumption of nutritional supplements, corticosteroids and HRT within the preceding one year. Also, the subjects consumed <4 cups of cola per week and <4 cups of tea/coffee per day. Additional inclusion criteria for female subjects involved regular menstrual cycle. Those excluded were individuals exhibiting other recognised causes of osteoporosis, including but not restricted to rheumatic diseases and endocrine disorders.

In order to maintain confidentiality and anonymity, each questionnaire was assigned a sequential code which was used during data entry and analysis. Socio-demographic details, including age, gender, year of study, were obtained through a self-administered questionnaire.

The international physical activity questionnaire [8] was administered to the participants and their level of PA was calculated as low, moderate or high via a series of 7 pre-set questions. Anthropometric measurements such as height and weight were measured from the respective subjects according to the National Health and Nutrition Examination Survey (NHANES) manual [9]. BMI was calculated using the standard formula BMI = weight in kilograms divided by height in meters squared. Wright's Peak Flow Meter (MicroPeak, Cardinal Health, UK) was used to obtain PEFR using sterilised mouth-pieces. In a standing position, the participants were instructed to deeply inspire followed by a quick and maximal forceful expiration into the flow meter [10]. The highest of three recordings was selected for assessment.

HGS of the dominant hand was measured with the aid of BIOPAC Hand dynamometer (SS25 LA S/N 12013156) and analysed by using the BIOPAC Student Lab software BSL R version 4.0.0). Each subject was seated in a standard position with the forearm flexed at a 90° angle from the elbow, and briefed beforehand on the proceedings. A maximum clench force was exerted followed by a sustained force of contraction till the reading declined to half of the maximum value [11].

Site-specific calcaneal BMD T scores was calculated using the Osteosys SONOST 3000 quantitative ultrasound scan (QUS) bone densitometer under the supervision of an experienced technician. By means of the quantitative ultrasound scan, the equipment measured two parameters of bone profile: broadband ultrasound attenuation (BUA) and the speed of sound (SOS). The structural feature of the bone, as a function of different attenuations of the ultrasound wave, was expressed as the BUA (Db/MHz). SOS (m/s) was a counter of the strength, elasticity and fragility by measuring the time taken for the ultrasound to travel through the calcaneus [12]. According to the World health Organisation (WHO) criterion, the obtained T scores were computed and interpreted as; osteoporosis <-2.5 SD, osteopenia -1.1 to -2.4, and normal -1.0 or higher) [2].

Data was analysed using SPSS 24. Shapiro-Wilk's test was used to assess the normality of continuous variables. The non-normally distributed quantitative variables were presented as medians and interquartile ranges (IQRs: Q3-Q1). Intergroup comparison of means was done using non-parametric Mann Whitney U test to verify the differences in gender. Spearman's rank correlation analysis was used to assess the association involving PEFR, HGS, BMD (T score), BMI and PA. In all cases, $p<0.05$ was taken as statistically significant.

Results

Of the 102 subjects, 52(50.9%) were males and 50(49%) were females. Based on gender, there was a significant difference in height, weight, BMI, PEFR, HGS and BMD (Table 1).

Correlation between PEFR, HGS, BMD, BMI and PA was significant (Table 2).

Based on low, moderate and high categories of PA, PEFR, HGS and BMD were higher in subjects performing more exercise (Figure).

Discussion

To our knowledge, this is the first study exploring the association of HGS, PEFR and BMD in Pakistani population.

The results indicate that HGS and PEFR were moderately positively correlated with BMD (T score). This is in agreement with a study [7]. A higher PEFR was found in individuals with higher BMD. One study showed that kyphosis and vertebral fractures secondary to osteoporosis had a direct relationship with decline in vital capacity (VC) [13]. Another longitudinal study found that a decrease in the forced expiratory volume (FEV1) was associated with increased prevalence of osteoporosis during a 3-year follow up [14].

Likewise, the current study observed a correlation of PA with HGS and PEFR. This can be proposed to individuals engaging in a high level of PA having markedly increased levels of lung function evident from the higher peak flow rate. A similar positive correlation of PA was found with HGS. The mechano-responsive cells of the bone are known to be the osteocytes and osteoblasts. These cells respond to dynamic stress placed on the bone via strain-adaptive remodelling. Alterations in exercise levels due to occupational factors during early adulthood have a significant effect on the maintenance and generation of peak bone mass and thus compensatory exercise is highly relevant for bone health in young adults [15]. Peak bone mass is defined as the amount of bony tissue present at the end of the skeletal maturation. Physical exercise has been associated with higher peak bone mass in young adults independent of gender and vitamin D levels for both males and females [16]. There are primarily two methods to measure BMD: dual ray X-ray absorptiometry (DEXA) and QUS. While DEXA has long since been the gold standard for diagnosis of osteoporosis, it is an expensive test and not readily available everywhere. BMD T scores measured at the calcaneus using QUS have been proven to be highly correlated with BMD T scores measured using DEXA at the femoral neck, total femur and lumbar spine [17].

The Osteosys SONOST 3000 QUS bone densitometer was used to measure BMD in the current study. This particular machine has been used in various researches and, thus, its results are reliable and reproducible [18]. This particular device was used to investigate BMD in pre- and post-menopausal Pakistani women [19].

In a country where the healthcare system is absorbed in tackling infectious diseases and the population branding osteoporosis as a foreseeable disease of old age [20], the urgency of dealing with osteoporosis is not ranked as a priority. An ambulatory study setting in Lahore in 2013 revealed the prevalence of osteoporosis in 18.6% of the study population and osteopenia in 64.1% [21]. The mean age of the participants was 34 ± 11.8 years, which was different than the age group included in the current study. These figures disclose that an imperative intervention is required. The development of osteoporosis is characterised by a micro-architectural deterioration of bone tissue as well as contribution from extra-skeletal factors. Consequently, this proposes the shift of osteoporosis management from a reactive to a predictive field. To attain better management, it is important to comprehend both the physiological and lifestyle factors that contribute to a low bone mass as well as to identify the individuals at risk for osteoporosis. It is estimated that approximately one in two women and one in four men will suffer from osteoporotic fractures in their lifetime [22].

According to the WHO, globally, 23% of adults and 81% of adolescents do not meet the global recommendations on PA for health. The 2015 Insufficient Physical Activity country factsheet for Pakistan put these figures at 26% for adults and 84.5% for adolescents, and they were bound to increase if an intervention was not done [23]. The clinical implication of this work lies in the fact that patients with low HGS or expiratory flow rates should be investigated for loss of BMD due to limitations on PA imposed by their co-morbid conditions. QUS can be used to screen for low BMD in high-risk populations in lieu of DEXA in low-income or remote areas, such as basic health units (BHUs). Furthermore, QUS machines are more portable and reduce patient exposure to ionizing radiation [24]. It has been proven to be an effective tool to screen for osteoporosis.

Though not assessed in the current study, the effect of nutritional supplements, including vitamin D, vitamin E and calcium, has been reported in literature to have a marked positive effect on BMD. Likewise, individuals who underwent HRT showed increased levels [25]. Exercise serves to maintain BMD whereas dietary intake of calcium and vitamin D helps reverse bone loss. Previous BMD studies in Pakistani population revealed similar results regarding both genders having a low BMI being significantly susceptible to having a low BMD as well [26]. Nevertheless, a few variables affect BMD negatively too and are vital to be understood in order to establish a proactive approach against osteoporosis. These include consumption of alcohol and carbonated drinks, specifically cola. At the same time, individuals who are habitual smokers are susceptible to low BMD levels [25].

The WHO's Global Action Plan on Physical Activity 2018-2030 [27] aims at reducing physical inactivity by 10% by the year 2025 and 15% by 2030. As a member state of the World Health Assembly (WHA), the 4 objectives and 20 policy actions highlighted in the plan should be put into practice in Pakistan. Key among these are governmental support and enabling policies to promote physical activity with national targets that should be met. Physical education should be mandatory in the curriculum of schools and colleges at all levels for both genders in order to form a healthy habit from a very early age. Governmental programmes to create public parks and recreation spaces for the purpose of promoting PA should be enacted. Population-based interventions should be carried out, such as national awareness campaigns, aimed at educating the public about the importance of PA and positive lifestyle modifications to reduce the risk of non-communicable diseases. These measures will save the national exchequer billions by decreasing the disease burden of preventable problems.

The current study has limitations as the sample size was too small to validate the results for generalisation. Further studies are recommended with a larger sample, concurrently using a more extensive dietary assessment regarding intake levels of calcium and vitamin D.

Conclusion

High PEFR and HGS proved to be beneficial for improving the quality of BMD, thereby reducing fracture risk. PA had a role in enhancing PEFR and HGS in young adults. A protective effect of increasing BMI on the BMD of healthy adults was established.

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Table 1: Comparison of variables based on gender

	Males (n=52) Median (IQR)	**Females (n=50) Median (IQR)**	***p*-value***
Age (years)	21.00 (1)	21.00 (1)	0.399
Height (m)	1.74 (0.09)	1.61 (0.08)	**0.0001***
Weight (kg)	71.50 (13.8)	56.50 (13.8)	**0.0001***
BMI (kg/m^2)	23.95 (4.4)	21.70 (5.4)	**0.002***
PEFR (L/min)	505.00 (100)	302.50 (100)	**0.0001***
HGS (kg)	29.85 (13.1)	13.85 (5.3)	**0.0001***
T score	-0.50 (1.4)	-1.30 (1.0)	**0.0001***

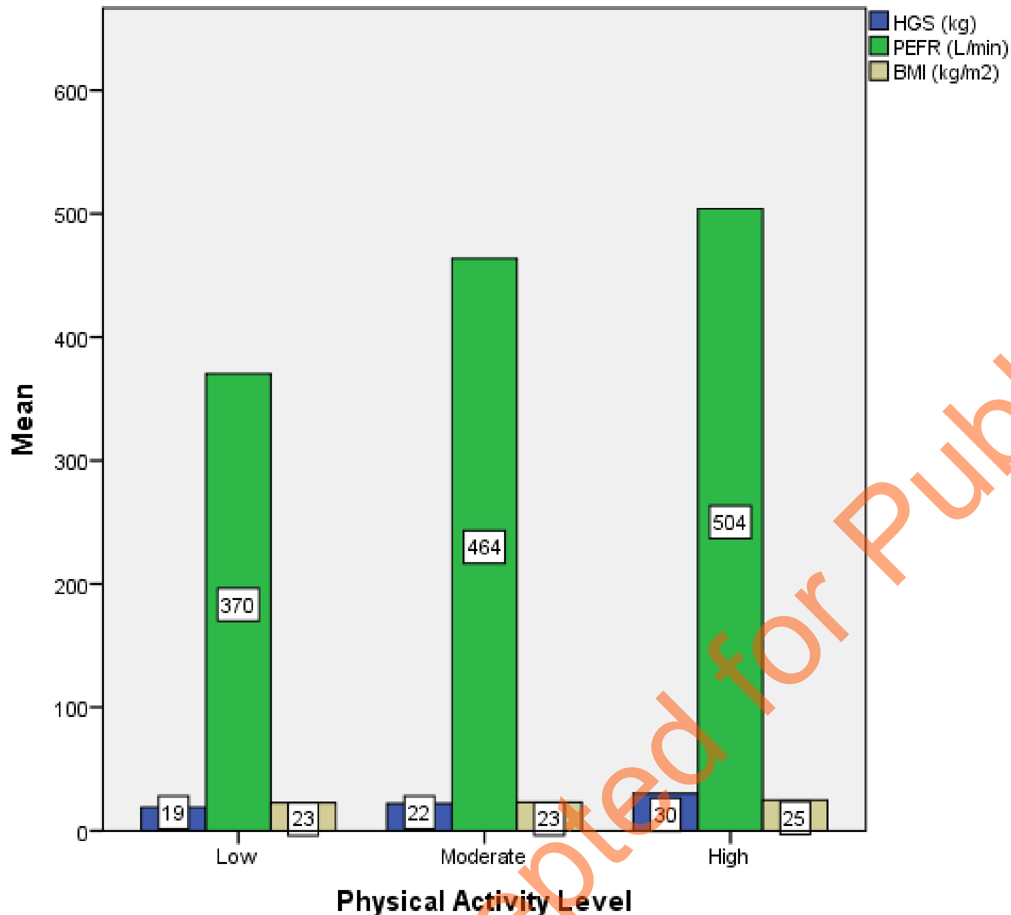
BMI: Body mass index, PEFR: Peak expiratory flow rate, HGS: Handgrip strength. P-value calculated by Mann Whitney U Test, *p<0.05 = statistically significant.

Table 2: Spearman correlation between PEFR, HGS, BMD, BMI, PA.

	PEFR (L/m)	**HGS (kg)**	**T score**	**BMI (kg/m^2)**	**PA**
PEFR (L/m) Correlation Coefficient Sig.	1.000 .	0.659 **0.001**	0.417 **0.001**	0.351 **0.001**	0.426 **0.001**

HGS (kg) Correlation Coefficient Sig	0.659 **0.001**	1.000 .	0.364 **0.001**	0.383 **0.001**	0.364 **0.001**
T score Correlation Coefficient Sig	0.417 **0.001**	0.364 **0.001**	1.000 .	0.462 **0.001**	0.238 **0.016**
BMI (kg/m^2) Correlation Coefficient Sig	0.351 **0.001**	0.383 **0.001**	0.462 **0.001**	1.000 .	0.151 **0.130**
PA Correlation Coefficient Sig	0.426 **0.001**	0.364 **0.001**	0.238 **0.016**	0.151 **0.130**	1.000 .

p-value <0.05 = statistically significant. PEFR: Peak expiratory flow rate, HGS: Handgrip strength, BMI: Body mass index, PA: Physical activity.



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364 **Figure:** Peak expiratory flow rate (PFER), Handgrip strength (HGS) and body
365 mass index **(BMI) values for young adults based on physical activity (PA)**
366 **expressed in categories.**
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