Research Article Science, Engineering and Health Studies 2020, 14(1), 8-21

Relationship between muscle strength, physical performance, quality of life and bone mineral density among postmenopausal women at risk of osteoporotic fractures

Siew Kuan Chua[1, 2], Devinder Kaur Ajit Singh[1*], Khairunisa Zubir[1], Yin Yian Chua[1, 3], Bala S Rajaratnam[4] and Sabarul Afian Mokhtar[5]

[1]Physiotherapy Program and Centre for Healthy Ageing & Wellness, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Kuala Lumpur 50300, Malaysia
[2]Center of Physiotherapy, Faculty of Health Sciences, Universiti Teknologi MARA Selangor branch, Puncak Alam Campus, Selangor 42300, Malaysia
[3]Woodlands Health Campus, 9 Maxwell Road, MND Complex Annex A #03-01, 069112 Singapore
[4]Rehab Services Division, St Lukes Hospital, 659674 Singapore
[5]Department of Orthopaedics & Traumatology, Faculty of Medicine, Universiti Kebangsaan Malaysia, Kuala Lumpur 56000, Malaysia
[*]Corresponding author: devinder@ukm.edu.my

Received: October 25, 2019; Revised: February 1, 2020; Accepted: February 4, 2020

ABSTRACT

Information regarding the relationship between muscle strength, physical performance (PP), quality of life (QoL) and bone mineral density (BMD) in adults with osteoporosis is limited. The aim of this study was to determine the relationship between these four parameters and the determinants of lumbar spine BMD in postmenopausal women at risk of osteoporotic fractures. In this cross-sectional study, 50 participants aged 55 and above were recruited from an orthopaedic clinic. A hand dynamometer, a load cell system and short physical performance battery were used to measure hand grip strength (HGS), back extensor muscle strength (BEMS) and PP, respectively. To assess QoL and BMD, European QoL questionnaire and bone densitometry were used, respectively. WHO fracture calculator (FRAX®) results showed that postmenopausal women in this study were at moderate risk of major osteoporotic fractures (13.28 ± 7.10%) and had a high risk of hip fracture (3.35 ± 2.54%). Stepwise regression analysis demonstrated that greater HGS and body mass index (BMI) were determinants of lumbar BMD, accounting for 28.4% of total variance independent of age. Improved muscle strength and having a higher BMI could preserve lumbar BMD and prevent osteoporotic fractures in postmenopausal women.

Keywords: muscle strength; osteoporotic fracture; physical performance; postmenopausal women; quality of life

1. INTRODUCTION

Osteoporosis is a silent disease that can affect both men and women after the age of 50 (Tosteson et al., 2008). In Asian population, there is an increased incidence of hip fractures after age 65 (Cheung et al., 2016). Prevalence of osteoporosis among women in their midlife residing in urban areas of Malaysia was reported to be 24.1% (Lim et al., 2005). The prevalence

ISSN Online 2630-0087

of osteoporotic hip fractures in Malaysia is estimated to rise by 3.55-fold from 2018 to 2050, which will be considered as top on the list in the Asian region (Cheung et al., 2018). In a recent study among 367 urban Chinese women in their midlife, it was reported that more than 50% of the women had osteoporosis (Subramaniam et al., 2019). Identified risk factors for osteoporosis in middle age Malaysian women from low socioeconomic background were menopause, low education, increased age (Chan et al., 2020) and number of lifetime pregnancies (Chin et al., 2017).

Incidence and prevalence of osteoporosis is expected to rise in line with life expectancy and osteoporosis related fractures. Osteoporosis may result in simple forearm fracture to severe multiple fractures (Hallberg et al., 2004), resulting in detrimental consequences. Approximate half of those with hip fractures had loss of independence, mobility impairments and prolonged hospitalization (Dyer et al., 2016; Hallberg et al., 2004). Osteoporotic vertebral fractures that appear earlier in life compared to other osteoporotic related fractures are often not detected (Bottai et al., 2016; Delmas et al., 2005). Increase in thoracic kyphosis with significant pain and height loss (Bottai et al., 2016) can lead to decline in back extensor muscle strength (BEMS) and daily physical function (Hongo et al., 2012; Korkmaz et al., 2014). Reduced BEMS was found to be associated with early menopause (Mika et al., 2005; Zhou et al., 2013) that led to greater bone loss in postmenopausal women (Iki et al., 2006). Moreover, increased thoracic kyphosis and vertebral fractures were found to be predictors of future fractures (Katzman et al., 2016). Older adults who had osteoporotic fractures either in the pelvis, wrist or vertebral spine were reported to have significantly lower quality of life (QoL) (Jun et al., 2015; Jung et al., 2017).

Decline in physical performance (PP) and muscle strength are associated with ageing (Landi et al., 2017). Lower PP assessed using either gait speed, repeated chair stands, leg power, or hand grip strength (HGS) were substantially associated with lower bone mineral density (BMD) at lumbar spine and hip regions (Arima et al., 2017; Cawthon et al., 2014). Increased risk of osteoporotic vertebral fractures was associated with lower scores in PP measures, repeated chair stands, leg power, narrow walk, and HGS (Cawthon et al., 2014). In addition, individuals with more than one osteoporotic vertebral fracture had declined physical function namely muscle strength and balance (Arima et al., 2017).

Information in regard to factors such as physical function and quality of life among postmenopausal women at risk of osteoporotic fractures is limited in our local population. Identifying these risk factors could assist in effective prevention and management strategies in women with risk of osteoporotic fractures. Hence, in this study, we aimed to examine the relationship between muscle strength, PP, QoL and BMD and the determinants of lumbar spine BMD in postmenopausal women at risk of osteoporotic fractures.

2. MATERIALS AND METHODS

In this cross-sectional study, a purposive sampling method was used, and it was conducted at the orthopaedic clinic, Hospital Canselor Tuanku Muhriz, Universiti Kebangsaan Malaysia. There is a specialised osteoporosis or bone health care team at this hospital and clients are provided optimum care with early screening and intervention. Sample size calculation was based on Bartlett et al. (2001) using optimal ratio of ten to one in multiple regression analysis. Hence, for five independent variables (age, body mass index (BMI), hand grip strength, BEMS and PP), the minimum acceptable sample size required was 50 (5×10). In this study, we recruited 50 postmenopausal women aged 55 years old and above who had a BMD report from February 2017 to May 2017, able to walk and were independent in activities of daily living. We excluded the participants if they had chronic back pain with numerical rating pain score of more than 4, had prior spine surgery, history of fractures and dislocations of the spine, had any known underlying pathologies such as tumor, spinal infections, tuberculosis, and had any inflammatory joint disease which may affect walking speed and grip strength tests. After receiving participants' written consent, their sociodemographic data including education level, comorbidity, history of falls, back pain, lifestyle and physical activity was obtained. We calculated their 10-year probability of osteoporotic fracture using fracture calculator World Health Organization's (WHO) FRAX® (www.shef.ac.uk/FRAX) with age, sex, weight, height, clinical risk factors and the result of femoral neck BMD. The dichotomized risk factors included prior fragility fracture, a parental history of hip fracture, current smoking and alcohol intake of three or more units daily, use of glucocorticoids for more than 3 months, rheumatoid arthritis, and secondary osteoporosis. Singapore model was used as FRAX has not been calibrated in Malaysia (Kanis et al., 2008). Ten-year risk of hip fracture of ≥3% or a ten-year risk of a major osteoporosis-related fracture (proximal part of the humerus, the wrist, or the hip or a clinical vertebral fracture) of ≥20% is regarded as a high risk of osteoporotic fracture. T-score was based on the WHO diagnostic categories, where individuals with T-score within 1 standard deviation (SD) of the norm are considered to have normal BMD. Scores below this norm are indicated in negative numbers. T-score between -2.5 to -1 and below -2.5 are categorised as osteopenia and osteoporosis, respectively (https://www.bones.nih.gov, Oct 2018). This study was approved by the Medical Research and Ethic Committee of Universiti Kebangsaan Malaysia (UKM PPI/111/8/JEP-2016-6580).

We measured QoL using self-rated questionnaire, 5-level EuroQol 5-dimensional questionnaire (EQ-5D-5L). It is an easy, quick and cognitively undemanding questionnaire to administer with availability in both Malay and English versions. EQ-5D-5L has been shown to have better psychometric performance compared to EQ-5D-3L (Shafie et al., 2019). EQ-5D-5L quantifies 5-domains: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. The Malay, Tamil and Mandarin versions of EQ-5D-3L have been evaluated in Malaysia with an ICC of <0.01 to 0.92 and Spearman's rho from 0.61 to 0.86 (Varatharajan and Chen, 2012). Participants' reported a Likert scale of 'no', 'mild' 'moderate', 'severe' or 'extreme' problems. The QoL is derived from EQ-VAS. Participants rated their health status on a visual analogue scale (EQ-VAS), where 0 and 100 corresponded to worst and best health imagined, respectively.

We measured PP using Short Physical Performance Battery (SPPB). SPPB consist of three tests: standing balance (static), usual walking speed (2.44-m course), and timed five-times repeated chair stand (Guralnik et al., 1994). SPPB has been shown to have predictive validity in terms of disability, nursing home admission and risk of mortality (Guralnik et al., 2000). Reliability of 0.87 was demonstrated for SPPB (Gomez-Cabello et al., 2012). Participants with total SPPB score between 0-6, 7-9 and 10-12 are categorized as poor, fair and good performance, respectively.

Dominant HGS was measured using a hand-held dynamometer (Jamar, White Plains NY 10602, USA). The handle was placed in the second position in order to get the most reliable and valid results (Fess, 1992) as recommended by the American Society of Hand Therapists. Good reliability of HGS test has been demonstrated with ICCs of 0.97 to 0.98 among nursing home and community-dwelling older adults (Vermeulen et al., 2015). Participants were instructed to grip as hard as they could for 5 seconds and rest for 5 seconds to register maximum reading (Innes, 1999). The maximum value of two most powerful grips was recorded.

BEMS was measured using a load cell (LC501-200/N sensor, Load cell, 200lb, 3MV/V, Newport

Electronic, Inc, US) that was connected to participants' upper trunk. This procedure has been documented in detail in our earlier report (Chua et al., 2017). Participants were required to lie prone with 0.2 m diameter of pad under the abdomen to minimize exaggerating degree of lumbar lordosis (Demoulin et al., 2012). They were instructed to lift their upper back and sustain maximum voluntary contraction for five seconds. This test was repeated twice with a 60-second rest in between tests (Müller et al., 2010) and the best value was used for analysis. This test is deduced to induce less spine loading and limit risk of excessive lordosis with good reliability (0.94-0.96) (Shum et al., 2010).

The data was analyzed using the Statistical Package for Social Science (SPSS) version 22. The significant level was set at $p<0.05$. The socio-demographic and risk of osteoporotic fracture data were analyzed using mean and standard deviation. The comorbidity, lifestyle, educational and employment status data are presented in total number and percentage as in Table 1. Shapiro-Wilks test was used to determine the normality of the data distribution. The 2 tailed Pearson correlations measure was performed to examine the correlation between PP, HGS, BEMS, QoL and BMD at lumbar. Based on Field (2011), correlation values of ±.1, ±.3 and ±.5 represent a small, medium and large effect, respectively. BMI and age were included in the regression to account for its potential effects on BMD. We employed stepwise multiple linear regression analysis to examine the causal relationship of BMD at lumbar spine with HGS, BEMS, SPPB, age and BMI as independent variables. No multicollinearity problem was observed on the tolerance value, 0.98 (>0.10) and a VIF value 1.02 (< 10), indicating that there were no multicollinearity problems in this model (Daoud, 2017).

3. RESULTS

Table 1 shows sociodemographic characteristics, risk factors of osteoporotic fracture, comorbidity, HGS, BEMS, PP and QoL of the participants. About 38% participants were overweight and obese. Overall, the participants were categorized to have osteopenia at lumbar spine and hip, at moderate risk of major osteoporotic fracture and high risk of hip fracture (3.35 ± 2.54%). Nearly 1/5 of the participants had menopaused before the age of 45 years. More than half of them had chronic back pain, nearly 1/4 had history of bone fractures, 1/5 had history of a fall in the past one year, 14% of participants' parents experienced osteoporotic fractures.

Table 1 Demographic characteristics of the participants

Variables	**Mean ± SD**	**N (%)**	**Range**
Age (years)	66.8 ± 6.88		55 - 81
75 - 84		10 (20%)	
65 - 74		18 (36%)	
55 - 64		22 (44%)	
BMI (kg/m²)	24.28 ± 5.07		16.7 - 41.08
T-score Lumbar BMD (osteopenia -2.5 to -1.0)	-1.33 ± 1.34		-4 - 2.20
T-score Hip (osteopenia, -2.5 to -1.0)	-1.13 ± 1.13		-4 - 0.9
FRAX®, Risk of major osteoporotic fracture	13.28 ± 7.10		2.8 - 28

Table 1 Demographic characteristics of the participants (Continued)

Variables	Mean ± SD	N (%)	Range
low risk <10%		19 (38%)	
moderate risk = 10% -19.9%,		23 (46%)	
high risk ≥20%		8 (16%)	
FRAX®, Risk of hip fracture	3.35 ± 2.54		0.2 - 9.9
low risk (<3%)		26 (52%)	
high risk (≥3%)		24 (48%)	
Race			
Malay		14 (28%)	
Chinese		31 (62%)	
Indian		5 (10%)	
Employment status			
Employed		4 (8%)	
Retired		35 (70%)	
Housewife		11 (22%)	
Educational level			
>primary education		38 (66%)	
Primary education		8 (16%)	
None		4 (8%)	
Present of hypertension		25 (50%)	
Present of type II Diabetes Mellitus		10 (20%)	
Present of back pain		31 (62%)	
Practice regular exercise (3 times/week)		29 (58%)	
Present of history of fall		10 (20%)	
Present of menopause before 45 years old		6 (12%)	
History of fractures		13 (26%)	
Present of parent's history of osteoporosis		7 (14%)	
On glucocorticoids		1 (2%)	
Present of rheumatoid Arthritis		4 (8%)	
Present of secondary osteoporosis		1 (2%)	
Dominant grip strength (kg)	11.6 ± 5.2		1.17 - 24
Back extensor muscle strength (Nm)	13.6 ± 2.3		9.12 - 19.2
Short Physical Performance Battery (SPPB) (score)	10.9 ± 1.6		7 - 12
EQ-VAS score	77.1 ± 14.6		50 - 100

Table 1 Demographic characteristics of the participants (Continued)

Variables	Mean ± SD	N (%)	Range
5-domain of EQ-5D-5L, dichotomous			
Domain mobility (have problem)		24 (48%)	
Domain self-care (have problem)		3 (6%)	
Domain usual activities (have problem)		12 (24%)	
Domain pain/discomfort (have problem)		36 (72%)	
Domain anxiety/depression (have problem)		16 (32%)	

BMI=body mass index, FRAX=10-year probability of osteoporotic fracture, BMD=bone mineral density, EQ-VAS=; EQ-5D-5L=5-level EuroQol 5-dimensional questionnaire.

Table 2 depicts the correlation results between lumbar BMD and age, BMI, SPPB, BEMS, HGS and QoL in postmenopausal women at risk of osteoporotic fracture. The results showed that age, SPPB, BMI and HGS were moderately correlated with lumbar spine BMD in postmenopausal women.

Table 2 Pearson correlation coefficients between age, BMI, SPPB, BEMS, HGS, QoL and lumbar BMD

Variables	Lumbar BMD (r)	*p*-value
Age	-0.30	0.032*
Body Mass Index (BMI)	-0.44	0.002**
Short Physical Performance Score (SPPB)	0.34	0.016*
Back Extensor Muscle Strength (BEMS)	0.22	0.119
Dominant Hand Grip Strength (HGS)	-0.39	0.005**
EQ VAS score (QoL)	0.26	0.068

**Correlation is significant at the 0.05 level (2-tailed)*

***Correlation is significant at the 0.01 level (2-tailed)*

Both age and BMI appeared as potential confounders. After adjusting for age, SPPB score was not statistically related to the lumbar BMD, hence SPPB score was not included in the regression analysis. Both BMI ($p<0.01$) and HGS ($p < 0.05$) remained statistically related to BMD at lumbar spine with the magnitude of the percentage change in BMI and HGS more than 10% (16% and 28%, respectively) (Table 3).

Table 3 Simple linear and multiple regression analysis

Independent variable		Regression coefficient	T	*p*-value
Simple linear regression	BMI	0.109	3.147	0.003**
	HGS	0.1	2.924	0.005**
Multiple regression (Enter)	BMI	0.094	2.791	0.008**
	HGS	0.078	2.111	0.04*
	Age	-0.013	-0.455	0.652

BMI=body mass index, HGS=hand grip strength.
$^{*}p<0.05$, $^{**}p<0.01$

In the stepwise regression analysis, both BMI and HGS were found to be significant determinants of BMD at lumbar spine after adjusting for age (Table 4). The HGS accounted for 17.1% of the variance of lumbar BMD, whilst HGS and BMI combined accounted for 28.4% of the total variance in the lumbar BMD. The standardized beta value (β) for BMI (0.37) is slightly higher than HGS (0.34) in the model.

Table 4 Stepwise multiple linear regression analysis of the significant independent variables on BMD at lumbar spine

	B	SEB	Standardized beta vale (β)	*p*-value	Tolerance	VIF
Constant	-4.7	0.85				
BMI	0.097	0.03	0.37	.005**	0.98	1.01
HGS	0.087	0.02	0.34	.009**	0.98	1.02

BMI=body mass index, HGS=hand grip strength.
$^{*}p<0.05$, $^{**}p<0.01$

4. DISCUSSION

We aimed to examine the relationship between PP, HGS, BEMS, QoL and BMD at lumbar in postmenopausal women at risk of osteoporotic fractures. Our results suggested that greater HGS and BMI were determinants of lumbar BMD in postmenopausal women.

Postmenopausal women in our study had high mean SPPB scores. This result could be due to the fact that more than half (58%) of our participants were physically active as they performed physical activity at least three times per week, were independent, mobile and had good social support. These factors may be related to improved bone health and muscle strength, resulting in less pain, improved fitness and psychological well-being in adults with osteoporosis (Acree et al., 2006; Li et al., 2009). However, participants in our study had lower mean HGS scores in comparison to community dwelling women in the study by Lam et al. (2016). Declined HGS (Kim et al., 2012) and BEMS (Kasukawa et al., 2017; Singh et al., 2013) may likely be due to age-related changes in postmenopausal women.

Our results are similar to a previous study (Dhillon et al., 2005) that showed postmenopausal women with osteopenia/without osteoporosis had higher QoL. It is noteworthy that there were lesser number of participants with osteoporotic-related fractures in our study compared to the study reported by Bianchi et al. (2005) that included participants with previous vertebral fractures. The presence of osteoporotic-related fractures limit ones' social activities and consequently decreases QoL (Adachi et al., 2010; Huang et al., 2015; Solimeo et al. 2012).

Our study results also showed that PP measured using SPPB and HGS were moderately correlated with lumbar spine BMD in postmenopausal women. This result is consistent with another study among postmenopausal women (mean aged 68.0 ± 1.8 years) that showed an association between BMD at spine and hip and PP which was examined using one leg stand (Kärkkäinen et al., 2009). In addition to lumbar and hip, the relationship was observed between BMD at forearm and physical performance measures using normal and eight-meter brisk gait speed, normal step length, brisk step length, timed one-leg stance, timed sit to stand and HGS tests (Lindsey et al., 2005). Greater HGS was significantly correlated with lower bone loss at both femoral neck and lumbar spine (Sirola et al., 2006). HGS has greater impact on BMD of the forearm (Orwoll et al., 1996) and could have been due to the direct influence of this anatomical site compared to other skeletal sites (Bauer et al., 1993).

However, our finding on BEMS was contradictory to previous studies (Crepaldi et al., 2007; Imagama et al., 2011) which showed that a decreased BEMS was positively related to BMD at lumbar spine in post-menopausal women with osteoporosis. The reason for our contradictory study results may attributed to the fact that participants in our study were categorized as osteopenia and not osteoporosis. Although general muscle strength decline was noted using HGS, it was not the case for BEMS. Decline in BEMS, and changes the compression forces at the lumbar spine lead to a decrease in BMD and osteoporotic vertebral fractures in older adults (Mika et al., 2005; Zehnacker and Bemis-Dougherty, 2007). Further investigation regarding BEMS and BMD of lumbar spine is warranted among people with osteoporosis.

Aging and declined BMI are clinical risk factors for osteoporotic related fractures (Bianchi et al., 2005). Age was identified as a confounding factor in our study as the magnitude of the percentage change in BMI and HGS was more than 10% after adjusting for age. Generally, aging is associated with morphological changes in the spine (Singh et al., 2010; 2011a; 2011b; 2013) and muscle strength measured using HGS (Werle et al., 2009). Women after menopause and age 80 years above are reported to have 48% of axial bone mass loss (Riggs and Melton, 1986).

From the regression analysis, the standardized beta value (β) for BMI was higher than HGS in the model after adjusting for age. This result may indicate that BMI is a more robust parameter compared to HGS as a determinant of BMD at lumbar spine in postmenopausal women with osteopenia as in this study. HGS was reported to be associated with BMD at both spine and femoral neck in men and women with osteoporosis independent of body size in previous studies (Dixon et al., 2005; Lim et al., 2004). Similarly, BMI has been found to be a determinant of BMD in postmenopausal women with osteoporosis (Morin et al., 2009; Rexhepi et al., 2015).

Although there was a significant correlation between SPPB score and BMD at lumbar spine, SPPB score did not appear to be a determinant of BMD at lumbar spine in this study. It can be deduced that other parameters such as BMI and HGS have accounted for its effects. In a previous study (Sakazaki et al., 2012), maximum gait speed was proposed to have better osteogenic effect on bone mass compared to usual gait speed. Our results suggest that age and lower body function (SPPB score) have a lesser effect compared to muscle strength and body mass on BMD at lumbar spine in postmenopausal women with osteopenia.

We found an association between muscle strength (measured using HGS) and BMI with BMD at lumbar spine. Our findings are supported by previous studies (Beyazal et al., 2016; Lindsey et al., 2005), suggesting muscle strengthening and maintaining ideal body mass as a prevention strategy in the management of osteoporosis and osteoporotic related fractures. Although it was an efficient way to identify the factors associated with BMD at lumbar spine, our study was cross sectional in design.

One of the limitations in this study is that the causal relationship between BMD at lumbar and BMI, grip strength and quality of life could not be established as it was cross-sectional in design. Also, QoL and muscle strength were not evaluated over time with intervention. A longitudinal study with larger samples and involving multicentre could be useful to confirm the results in the present study. Secondly, the relationship between BMD at lumbar spine, HGS and BMI could not be explained fully in this study. This is probably because the effects of lumbar BMD may be influenced by several other factors such as bone remodelling, years of menopause, nutrition, muscle mass, bone turnover and quality of bone. Finally, the participants were recruited using a non-randomized sampling method in a hospital setting, which limits the generalization of the results to all postmenopausal women.

The strength of this study is that we included general, back extensor muscle strength and physical performance measures as determinants in postmenopausal women with risk of osteoporotic fractures. Our study results may be useful for planning prevention strategies via early diagnosis and treatment in postmenopausal women.

5. CONCLUSION

The study findings indicate that muscle strength and BMI are related to BMD at lumbar spine. We suggest optimizing muscle strength and maintaining an ideal BMI as a prevention strategy for osteoporotic-related fractures in postmenopausal women. Clinically, hand grip strength and BMI could also be used to predict BMD at lumbar spine in older adults where bone densitometry is not available.

ACKNOWLEDGEMENT

This study was funded using a grant from Ministry of Higher Education through Universiti Kebangsaan Malaysia (ERGS 1/2012/SKK/UKM/02/2). We would like to express our utmost gratitude to all the participants, staff from Orthopedic Clinic and Physiotherapy Department of Hospital Canselor Tuanku Muhriz for their cooperation and assistance.

REFERENCES

Acree, L. S., Longfors, J., Fjeldstad, A. S., Fjeldstad, C., Schank, B., Nickel, K. J., Montgomery, P. S., and Gardner, A. W. (2006). Physical activity is related to quality of life in older adults. *Health Qual Life Outcomes*, 4, 37.

Adachi, J. D., Adami, S., Gehlbach, S., Anderson Jr, F. A., Boonen, S., Chapurlat, R. D., Compston, J. E., Cooper, C., Delmas, P., Díez-Pérez, A., and Greenspan, S. L. (2010). Impact of prevalent fractures on quality of life: baseline results from the global longitudinal study of osteoporosis in women. *Mayo Clinic Proceedings*, 85(9), 806-813.

Arima, K., Abe, Y., Nishimura, T., Okabe, T., Tomita, Y., Mizukami, S., Kanagae, M., and Aoyagi, K. (2017). Association of vertebral compression fractures with physical performance measures among community-dwelling Japanese women aged 40 years and older. *BMC Musculoskelet Disord*, 18, 176.

Bauer, D. C., Browner, W. S., Cauley, J. A., Orwoll, E. S., Scott, J. C., Black, D. M., Tao, J. L., and Cummings, S. R. (1993). Factors associated with appendicular bone mass in older women. *Annals of Internal Medicine*, 118(9), 657-665.

Beyazal, M. S., Devrimsel, G., Türkyılmaz, A. K., and Yıldırım, M. (2016). The relationship of hand grip strength with bone mineral density and vitamin D in postmenopausal women. *Turkish Journal of Osteoporosis*, 22, 1-6.

Bianchi, M. L., Orsini, M. R., Saraifoger, S., Ortolani, S., Radaelli, G., and Betti, S. (2005). Quality of life in post-menopausal osteoporosis. *Health Qual Life Outcomes*, 3, 78.

Bottai, V., Giannotti, S., Raffaetà, G., Mazzantini, M., Casella, F., De Paola, G., Menconi, A., Falossi, F., and Guido, G. (2016). Underdiagnosis of osteoporotic vertebral fractures in patients with fragility fractures: retrospective analysis of over 300 patients. *Clinical Cases in Mineral and Bone Metabolism*, 13(2), 119-122.

Cawthon, P. M., Blackwell, T. L., Marshall, L. M., Fink, H. A., Kado, D. M., Ensrud, K. E., Cauley, J. A., Black, D., Orwoll, E. S., Cummings, S. R., and Schousboe, J. T. (2014). Physical performance and radiographic and clinical vertebral fractures in older men. *Journal of Bone and Mineral Research*, 29(9), 2101-2108.

Chan, C. Y., Subramaniam, S., Mohamed, N., Ima-Nirwana, S., Muhammad, N., Fairus, A., Ng, P. Y., Jamil, N. A., Abd Aziz, N., and Chin, K. Y. (2020). Determinants of bone health status in a multi-ethnic population in Klang Valley, Malaysia. *International Journal of Environmental Research and Public Health*, 17(2), 384.

Cheung, E. Y., Tan, K. C., Cheung, C. L., and Kung, A. W. (2016). Osteoporosis in East Asia: Current issues in assessment and management. *Osteoporos Sarcopenia*, 2(3), 118-133.

Cheung, C. L., Ang, S. B., Chadha, M., Chow, E. S. L., Chung, Y. S., Hew, F. L., Jaisamrarn, U., Ng, H., Takeuchi, Y., Wu, C. H., and Xia, W. (2018). An updated hip fracture projection in Asia: the Asian Federation of Osteoporosis Societies study. *Osteoporos Sarcopenia*, 4(1), 16-21.

Chin, K. Y., Low, N. Y., Dewiputri, W. I., and Ima-Nirwanaa, S. (2017). Factors associated with bone health in Malaysian middle-aged and elderly women assessed via quantitative ultrasound. *International Journal of Environmental Research and Public Health*, 14(7), 736.

Chua, S. K., Singh, D. K., Rajaratnam, B. S., Mokhtar, S. A., Sridharan, R., Gan, K. B., Chin, K. Y., and Lee, R. Y. W. (2017). A study protocol: spinal morphology, physical performance, quality of life and biochemical markers in adults at risk of osteoporotic fractures. *Pertanika Journal of Science and Technology*, 25(4), 1123-1134.

Crepaldi, G., Romanato, G., Tonin, P., and Maggi, S. (2007). Osteoporosis and body composition. *Journal of Endocrinological Investigation*, 30(suppl 6), 42-47.

Daoud, J. I. (2017). Multicollinearity and regression analysis. *Journal of Physics: Conference Series*, 949(1), 012009.

Delmas, P. D., van de Langerijt, L., Watts, N. B., Eastell, R., Genant, H., Grauer, A., and Cahall, D. L. (2005). Underdiagnosis of vertebral fractures is a worldwide problem: the IMPACT study. *Journal of Bone and Mineral Research*, 20(4), 557-563.

Demoulin, C., Grosdent, S., Smeets, R., Verbunt, J., Jidovtseff, B., Mahieu, G., Crielaard, J. M., and Vanderthommen, M. (2012). Muscular performance assessment of trunk extensors: A critical appraisal of the literature. In *Low Back Pain* (Ali Asghar Norasteh., ed). pp. 141-165. [OnlineURL: www.intechopen.com/books/low-back-pain/muscular-performance-assessment-of-trunk-extensors-a-critical-appraisal-of-the-literature] accessed on April 15, 2018.

Dhillon, V., Hurst, N., Hannan, J., and Nuki, G. (2005). Association of low general health status measured prospectively by Euroqol EQ5D, with osteoporosis, independent of a history of prior fracture. *Osteoporosis International*, 16(5), 483-489.

Dixon, W. G., Lunt, M., Pye, S. R., Reeve, J., Felsenberg, D., Silman, A. J., and O'neill, T. W. (2005). Low grip strength is associated with bone mineral density and vertebral fracture in women. *Rheumatology*, 44(5), 642-646.

Dyer, S. M., Crotty, M., Fairhall, N., Magaziner, J., Beaupre, L. A., Cameron, I. D., and Sherrington, C. (2016). A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatrics*, 16, 158.

Fess, E. E. (1992). Grip strength. In *Clinical Assessment Recommendations* (Casanova J. S. ed.), 2nd, pp. 41-45, Chicago: American Society of Hand Therapists.

Field, A. (2011). *Discovering Statistics using SPSS*, 3rd, SAGE Publications Ltd., pp. 13.

Gomez-Cabello, A., Ara, I., González-Agüero, A., Casajus, J. A., and Vicente-Rodriguez, G. (2012). Effects of training on bone mass in older adults. *Sports Medicine*, 42(4), 301-325.

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., Scherr, P. A., and Wallace, R. B. (1994). A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *Journal of Gerontology*, 49(2), M85-M94.

Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., Studenski, S., Berkman, L. F., and Wallace, R. B. (2000). Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *Journal of Gerontology: Medical Sciences*, 55(4), M221-M231.

Hallberg, I., Rosenqvist, A. M., Kartous, L., Löfman, O., Wahlström, O., and Toss, G. (2004). Health-related quality of life after osteoporotic fractures. *Osteoporosis International*, 15(10), 834-841.

Hongo, M., Miyakoshi, N., Shimada, Y., and Sinaki, M. (2012). Association of spinal curve deformity and back extensor strength in elderly women with osteoporosis in Japan and the United States. *Osteoporosis International*, 23(3), 1029-1034.

Huang, C. Y., Liao, L. C., Tong, K. M., Lai, H. L., Chen, W. K., Chen, C. I., Lu, C.Y., and Chen, F. J. (2015). Mediating effects on health-related quality of life in adults with osteoporosis: a structural equation modelling. *Osteoporosis International*, 26(3), 875-883.

Iki, M., Saito, Y., Kajita, E., Nishino, H., and Kusaka, Y. (2006). Trunk muscle strength is a strong predictor of bone loss in postmenopausal women. *Clinical Orthopaedics and Related Research*, 443, 66-72.

Imagama, S., Matsuyama, Y., Hasegawa, Y., Sakai, Y., Ito, Z., Ishiguro, N., and Hamajima, N. (2011). Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. *European Spine Journal*, 20(6), 954-961.

Innes, E. (1999). Handgrip strength testing: A review of the literature. *Australian Occupational Therapy Journal*, 46(3), 120-140.

Jun, H. J., Kim, K. J., Lee, J. S., and Yang, S. H. (2015). Association between osteoporotic fractures and quality of life based on the Korean Community Health Survey of 2010. *Journal of Physical Therapy Science*, 27(10), 3325-3328.

Jung, H. J., Park, Y. S., Seo, H. Y., Lee, J. C., An, K. C., Kim, J. H., Sin, B. J., Kang, T. W., and Park, S. Y. (2017). Quality of life in patients with osteoporotic vertebral compression fractures. *Journal of Bone Metabolism*, 24(3), 187-196.

Kanis, J. A., Johnell, O., Odén, A., Johansson, H., and McCloskey, E. (2008). FRAX™ and the assessment of fracture probability in men and women from the UK. *Osteoporosis International*, 19(4), 385-397.

Kärkkäinen, M., Rikkonen, T., Kröger, H., Sirola, J., Tuppurainen, M., Salovaara, K., Arokoski, J., Jurvelin, J., Honkanen, R., and Alhava, E. (2009). Physical tests for patient selection for bone mineral density measurements in postmenopausal women. *Bone*, 44(4), 660-665.

Kasukawa, Y., Miyakoshi, N., Hongo, M., Ishikawa, Y., Kudo, D., Suzuki, M., Mizutani, T., Kimura, R., Ono, Y., and Shimada, Y. (2017). Age-related changes in muscle strength and spinal kyphosis angles in an elderly Japanese population. *Clinical Interventions in Aging*, 12, 413-420.

Katzman, W. B., Vittinghoff, E., Kado, D. M., Lane, N. E., Ensrud, K. E., and Shipp, K. (2016). Thoracic kyphosis and rate of incident vertebral fractures: the Fracture Intervention Trial. *Osteoporosis International*, 27(3), 899-903.

Kim, S. W., Lee, H. A., and Cho, E. H. (2012). Low handgrip strength is associated with low bone mineral density and fragility fractures in postmenopausal healthy Korean women. *Journal of Korean Medical Science*, 27(7), 744-747.

Korkmaz, N., Tutoğlu, A., Korkmaz, I., and Boyacı, A. (2014). The relationships among vitamin D level, balance, muscle strength, and quality of life in postmenopausal patients with osteoporosis. *Journal of Physical Therapy Science*, 26(10), 1521-1526.

Bartlett, J. E., Kotrlik, J. W., and Higgins, C. C. (2001). Organizational research: Determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal*, 19(1), 43-50.

Lam, N. W., Goh, H. T., Kamaruzzaman, S. B., Chin, A. V., Poi, P. J. H., and Tan, M. P. (2016). Normative data for hand grip strength and key pinch strength, stratified by age and gender for a multiethnic Asian population. *Singapore Medical Journal*, 57(10), 578-584.

Landi, F., Calvani, R., Tosato, M., Martone, A. M., Fusco, D., Sisto, A., Ortolani, E., Savera, G., Salini, S., and Marzetti, E. (2017). Age-related variations of muscle mass, strength, and physical performance in community-dwellers: results from the Milan EXPO survey. *Journal of the American Medical Directors Association*, 18(1), 88.e17-88.e24

Li, W. C., Chen, Y. C., Yang, R. S., and Tsauo, J. Y. (2009). Effects of exercise programmes on quality of life in osteoporotic and osteopenic postmenopausal women: a systematic review and meta-analysis. *Clinical Rehabilitation*, 23(10), 888-896.

Lim, S., Joung, H., Shin, C. S., Lee, H. K., Kim, K. S., Shin, E. K., Kim, H. Y., Lim, M. K., and Cho, S. I. (2004). Body composition changes with age have gender-specific impacts on bone mineral density. *Bone*, 35(3), 792-798.

Lim, P. S., Ong, F. B., Adeeb, N., Seri, S. S., Noor-Aini, M. Y., Shamsuddin, K., Hapizah, N., Mohamed, A. L., Mokhtar, A., and Wan, H. W. H. (2005). Bone health in urban midlife Malaysian women: risk factors and prevention. *Osteoporosis International*, 16(12), 2069-2079.

Lindsey, C., Brownbill, R. A., Bohannon, R. A., and Ilich, J. Z. (2005). Association of physical performance measures with bone mineral density in postmenopausal women. *Archives of Physical Medicine and Rehabilitation*, 86(6), 1102-1107.

Mika, A., Unnithan, V. B., and Mika, P. (2005). Differences in thoracic kyphosis and in back muscle strength in women with bone loss due to osteoporosis. *Spine*, 30(2), 241-246.

Müller, R., Strässle, K., and Wirth, B. (2010). Isometric back muscle endurance: an EMG study on the criterion validity of the Ito test. *Journal of Electromyography and Kinesiology*, 20(5), 845-850.

Morin, S., Tsang, J. F., and Leslie, W. D. (2009). Weight and body mass index predict bone mineral density and fractures in women aged 40 to 59 years. *Osteoporosis International*, 20(3), 363-370.

Orwoll, E. S., Bauer, D. C., Vogt, T. M., and Fox, K. M. (1996). Axial bone mass in older women. *Annals of Internal Medicine*, 124(2), 187-196.

Rexhepi, S., Bahtiri, E., Rexhepi, M., Sahatciu-Meka, V., and Rexhepi, B. (2015). Association of body weight and body mass index with bone mineral density in women and men from Kosovo. *Mater Sociomed*, 27(4), 259-262.

Riggs, B. L., and Melton, L. J. (1986). Involutional osteoporosis. *New England Journal of Medicine*, 314, 1676-1686.

Sakazaki, T., Koike, T., Yanagimoto, Y., and Oshida, Y. (2012). Association between gait speed and bone strength in community-dwelling postmenopausal Japanese women. *Environmental Health and Preventive Medicine*, 17, 394-400.

Shafie, A. A., Thakumar, A. V., Lim, C. J., and Luo, N. (2019). Psychometric performance assessment of Malay and Malaysian English version of EQ-5D-5L in the Malaysian population. *Quality of Life Research*, 28(1), 153-162.

Shum, G. L. K., Crosbie, J., and Lee, R. Y. W. (2010). Back pain is associated with changes in loading pattern throughout forward and backward bending. *Spine*, 35(25), E1472-E1478.

Singh, D. K. A., Bailey, M., and Lee, R. (2010). Biplanar measurement of thoracolumbar curvature in older adults using an electromagnetic tracking device. *Archives of Physical Medicine and Rehabilitation*, 91(1), 137-142.

Singh, D. K. A., Bailey, M., and Lee, R. Y. W. (2011a). Strength and fatigue of lumbar extensor muscles in older adults. *Muscle Nerve*, 44(1), 74-79.

Singh, D. K. A., Bailey, M., and Lee, R.Y. (2011b). Ageing modifies the fibre angle and biomechanical function of the lumbar extensor muscles. *Clinical Biomechanics*, 26(6), 543-547.

Singh, D. K. A., Bailey, M., and Lee, R. (2013). Decline in lumbar extensor muscle strength in older adults: correlation with age, gender and spine morphology. *BMC Musculoskeletal Disorders*, 14, Article number: 215.

Sirola, J., Rikkonen, T., Tuppurainen, M., Jurvelin, J. S., and Kröger, H. (2006). Association of grip strength change with menopausal bone loss and related fractures: a population-based follow-up study. *Calcified Tissue International*, 78(4), 218-226.

Solimeo, S. L., Silverman, S. L., Calderon, A. D., Nguyen, A., and Gold, D. T. (2012). Measuring health-related quality of life (HRQOL) in osteoporotic males using the Male OPAQ. *Osteoporosis International*, 23(3), 841-852.

Subramaniam, S., Chan, C. Y., Soelaiman, I. N., Mohamed, N., Muhammad, N., Ahmad, F., Manaf, M. R. A., Ng, P. Y., Jamil, N. A., and Chin, K. Y. (2019). Prevalence and predictors of osteoporosis among the Chinese population in Klang Valley, Malaysia. *Applied Sciences*, 9(9), 1820.

Tosteson, A. N. A., Melton, L. J., Dawson-Hughes, B., Baim, S., Favus, M. J., Khosla, S., and Lindsay, R. L. (2008). Cost-effective osteoporosis treatment thresholds: The United States perspective. *Osteoporosis International*, 19(4), 437-447.

Varatharajan, S., and Chen, W. S. (2012). Reliability and validity of EQ-5D in Malaysian population. *Applied Research Quality Life*, 7(2), 209-221.

Vermeulen, J., Neyens, J. C. L., Spreeuwenberg, M. D., van Rossum, E., Hewson, D. J., and de Witte, L. P. (2015). Measuring grip strength in older adults: comparing the grip-ball with the Jamar dynamometer. *Journal of Geriatric Physical Therapy*, 38(3), 148-153.

Werle, S., Goldhahn, J., Drerup, S., Simmen, B. R., Sprott, H., and Herren, D. B. (2009). Age-and gender-specific normative data of grip and pinch strength in a healthy adult Swiss population. *Journal of Hand Surgery (European Volume)*, 34(1), 76-84.

Zehnacker C. H., and Bemis-Dougherty, A. (2007). Effect of weighted exercises on bone mineral density in post- menopausal women a systematic review. *Journal of Geriatric Physical Therapy*, 30(2), 79-88.

Zhou, Z., Zheng, L., Wei, D., Ye, M., and Li, X. (2013). Muscular strength measurements indicate bone mineral density loss in postmenopausal women. *Clinical Interventions in Aging*, 8, 1451-1459.