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Exploring BMI categories and their association with fragility fractures in Thai men: a retrospective study at Burapha University Hospital

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ABSTRACT

Objectives To examine the association between body mass index (BMI) categories and the fragility fractures in Thai men and to identify the most common anatomical sites of these fractures. We hypothesised that BMI is associated with the risk of fragility fractures in this population.

Design Retrospective observational study.

Setting A tertiary care centre in eastern Thailand, based on data from Burapha University Hospital.

Participants The study included 419 Thai men aged 40 years or older who underwent bone mineral density (BMD) assessment between 2014 and 2022. Participants were classified according to the presence or absence of documented fragility fractures. Exclusion criteria included pathological fractures, high-energy trauma and incomplete BMI or BMD data.

Primary and secondary outcomes The primary outcome was the association between BMI categories and the risk of fragility fractures. The secondary outcome was the anatomical distribution of these fractures.

Results Among 419 participants, 147 (35.1%) had fragility fractures and 272 (64.9%) did not. Underweight men had significantly increased odds of fragility fractures (OR, 3.44; 95% CI, 1.03 to 11.47; p=0.044) and vertebral fractures (OR, 4.30; 95% CI, 1.36 to 13.58; p=0.013), compared with men of normal BMI. In contrast, overweight men had lower odds of overall fractures (OR, 0.50; 95% CI, 0.31 to 0.80; p=0.004) and vertebral fractures (OR, 0.48; 95% CI, 0.27 to 0.84; p=0.010). Among underweight participants, BMI was moderately positively correlated with BMD at the lumbar spine (r=0.607; p=0.028) and at the one-third radius (r=0.557; p=0.084).

Conclusions Lower BMI was significantly associated with increased risk of fragility fractures, particularly vertebral fractures. These findings support prior evidence in Asian populations and reveal a fracture pattern, predominantly vertebral followed by hip fractures, which differs from those observed in predominantly Caucasian populations.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study addresses a critical evidence gap by focusing on fragility fractures in Thai men, an underrepresented population.
- ⇒ Standardised dual-energy X-ray absorptiometry measurements at multiple sites (lumbar spine, femoral neck, total hip and 33% radius) ensure high data reliability.
- ⇒ The 8 year dataset provides sufficient power for subgroup analyses.
- ⇒ Retrospective design limits control of confounding factors and excludes key lifestyle data.
- ⇒ Single-centre and strict inclusion criteria may affect generalisability.

INTRODUCTION

Bone strength is determined by both bone mineral density (BMD) and bone quality.[1] Another crucial factor influencing bone health is the body mass index (BMI), which is a measure of body mass, calculated as weight in kilograms divided by the square of height in metres. There is evidence of a positive relationship between BMI and BMD or the risk of fractures. For example, a meta-analysis by Xiang *et al* (2017) found that a higher BMI could reduce the chance of fractures in men.[2] Similarly, research by Song *et al* (2020) found that a higher BMI could causally increase BMD.[3] A systematic review by Turcotte *et al* (2021) reported that obesity was linked with increased BMD and improved bone microarchitecture, and men with obesity had a lower probability of hip fractures.[4] Sampaio *et al* (2021) indicated that patients with a higher BMI had better bone mass and fewer fractures.[5] Lastly, Shiomoto *et al* (2021) found that being underweight was a significant risk factor for hip fractures in women and vertebral fractures in men.[6]

On the other hand, some studies suggest that BMI does not have a significant effect on BMD or the chance of fractures. For instance, Chan *et al*'s (2014) study found no direct impact of BMI on fractures in older Australian men, but there was an association mediated by femoral neck BMD.[7] Shen *et al*'s (2016) examination found that an increase in BMI was associated with increased BMD but not with major osteoporotic or hip fracture risks in men.[8] Lastly, Turcotte *et al*'s (2023) research found that higher BMI was significantly associated with only distal lower limb fracture but not with other types of fractures.[9]

The relationship between BMI, BMD and fracture probability is complex and can vary based on the design of the research, the characteristics of the population studied and the specific bone sites examined. The risk of fragility fractures is significantly influenced by bone structure, which varies across different ethnic groups. A meta-analysis highlighted the differences in fracture probability among five American ethnic groups.[10] Despite extensive investigation, a knowledge gap exists, especially concerning Asian men, as the majority of studies have focused on women.[2–4 6–9 11] This gap is of concern considering the ageing populations in many Asian countries and the anticipated increase in fragility fractures.

The lack of targeted research on Asian, especially Thai men, impedes the development of effective prevention strategies or treatment protocols for this group. Differences in culture, diet and lifestyle suggest that the risk factors and progression of the disease in Thai men may be different from other populations. Therefore, the primary objective of this study is to identify BMI categories as risk factors for fragility fractures in Thai men. The secondary aim is to identify the location of the fragility fracture. This research will help fill the knowledge gap and assist in the development of strategies to prevent and treat fragility fractures in this under-researched population, thereby promoting bone health and reducing the risk of fractures.

MATERIALS AND METHODS

This retrospective study, with data collected from 2014 to 2022, included male patients aged 40 years or older who underwent BMD assessment using dual-energy X-ray absorptiometry (DXA) at standard anatomical sites, including the lumbar spine (L1–L4), femoral neck, total hip and one-third (33%) radius. Inclusion required a complete clinical record and interpretable BMD measurements without technical artefacts or measurement errors. Patients were excluded if they had missing demographic, clinical or BMD data; uninterpretable DXA results due to factors such as metallic implants at the measurement site or significant motion artefacts; or medical conditions known to affect bone metabolism. These conditions included primary bone malignancies, bone metastases, end-stage chronic kidney disease (stages 4–5), endocrine disorders such as hyperparathyroidism or Cushing's syndrome, chronic or high-dose corticosteroid therapy (≥5 mg/day of prednisolone equivalent for ≥3 months) and genetic bone disorders such as osteogenesis imperfecta.

On obtaining informed consent, a trained technician collected the data, including demographic information, such as age, examination date, weight, height and history of previous fragility fractures. The review process involved a thorough examination of the hospital database, medical records, plain X-ray films, CT or MRI scans (if available) and self-reported data to identify prior fractures, specifically those occurring at the hip, distal forearm and vertebral regions. Only fragility fractures, defined as fractures sustained from force comparable to a fall from a standing position or less that would not have occurred in healthy bone (excluding fractures of the skull, face, fingers and toes), were considered for inclusion in this study.[12] The collection and analysis of data in the registry have been approved by the Ethics Committee of Burapha University (identifier number: HS016/2567).

BMI

The BMI was calculated as the individual's weight in kilograms divided by the square of their height in metres (kg/m²). The WHO categories were used to classify individuals into the following groups: (1) underweight: BMI less than 18.5, (2) normal weight: BMI between 18.5 and 24.9, (3) overweight: BMI between 25.0 and 29.9 and (4) obese: BMI 30.0 and above.[13]

BMD

Patient data, including the total number of examined sites, were recorded from the DXA machine and the Picture Archiving and Communication System for each year. Clinical data such as age, sex, BMI, fragility fractures, bone density and T-score values at the examined sites were collected and compared with the Asian population database of the DXA machine (GE-Lunar Prodigy advance). Bone density measurements were primarily taken at the lumbar spines and hip. If these sites could not be examined, the bone density at the 33% radius was used for diagnosis. The recorded data included bone mineral content and T-score values. Patients were then classified based on their bone density into four categories: (1) normal bone density (T-score −1.0 and above), (2) osteopenia (T-score between −1.0 and −2.5) and (3) osteoporosis (T-score −2.5 and below), according to the diagnostic criteria of the WHO.[14] All measurements were performed using the same DXA equipment throughout the study. The scan mode employed was the standard mode, using dual energy peaks at 38 keV (low) and 70 keV (high), with a pixel size/resolution of approximately 1 mm. The coefficient of variation for BMD measurements at key anatomical sites was as follows: lumbar spine (L1–L4) = 1.55%, femoral neck=1.11%, total hip=0.82% and 33% radius=1.2%, indicating high precision and reliability in measurement across all sites.

Exercise, tobacco and alcohol consumption

Exercise, tobacco use and alcohol consumption are critical factors affecting bone density.[15 16] However, it is imperative to acknowledge that our data is derived from a retrospective study. This methodological approach inherently limits our ability to collect comprehensive information regarding exercise habits, tobacco usage and alcohol consumption. The retrospective nature of the study means that we rely on pre-existing records, which often do not include detailed lifestyle factors. Consequently, the absence of this data restricts our capacity to fully assess the impact of these variables on bone density.

Statistical analysis

Demographic and clinical data will be summarised using descriptive statistics. Categorical variables, including the number of patients, age categories, BMI categories and diagnostic categories, will be expressed as numbers and percentages. Continuous variables, such as age at examination, BMI at examination and BMD at various sites, will be presented as means and SD or medians and interquartile ranges, as appropriate. The difference between group was compared using independent t-test and X^2 test. Binary logistic regression analysis will be employed to compute ORs for overall fragility fractures and site-specific fragility fractures, using the normal BMI category as the reference. The results will be reported as ORs with 95% CIs. The association between BMD and BMI was determined using Spearman correlation. For managing bias from missing data, the Hosmer–Lemeshow goodness-of-fit was used. A two-sided P value of less than 0.05 will be deemed statistically significant. The power of the study was set at 80% to detect statistically significant differences or associations. All analyses will be conducted using SPSS software (version 28.0, SPSS Institute).

RESULTS

The study involved 419 male patients, categorised into two groups: those without fractures (64.9%, 272 patients) and those with fractures (35.1%, 147 patients). The fracture group had a lower mean BMI (23.2±3.3 kg/m²) compared with the non-fracture group (24.4±3.3 kg/m²). When categorised by BMI, 61.3% of patients were in the normal range, 30.1% overweight, 5.3% obese and 3.3% underweight. BMD values were consistently lower in the fracture group across all measured sites: lumbar spine (0.933 vs 1.099 g/cm²), femoral neck (0.760 vs 0.888 g/cm²), total hip (0.822 vs 0.964 g/cm²) and 33% radius (0.843 vs 0.885 g/cm²). Overall, 44.9% of patients had osteopaenia, 37.2% had normal BMD and 17.9% had osteoporosis. Among those with fractures, osteopaenia was most common (46.9%), followed by osteoporosis (36.1%) and normal BMD (17.0%). In contrast, patients without fractures were more likely to have normal BMD (48.2%), followed by osteopaenia (43.8%) and osteoporosis (8.1%). There is a statistically significant difference between the two groups in diagnostic categories, BMD at the 33% radius and BMI categories, which were the measured outcomes. There is no statistical difference between both groups in age, BMI, BMD at the lumbar spine, femoral neck and hip (table 1).

Table 1 Demographic data and concurrent conditions among non-fracture and fracture participants (n=419)

Parameters	Non-fracture (n=272)	Fracture (n=147)	P value
Age at examination (year)			0.598
Range	49–91	51–96	
Mean (SD)	69.7 (8.9)	72.7 (8.8)	
BMI at examination (kg/m^2)			0.856
Range	15.8–41.3	14.7–32.9	
Mean (SD)	24.4 (3.3)	23.2 (3.3)	
BMI categories, n (%)			<0.001*
Underweight	4 (1.5)	9 (6.1)	
Normal	156 (57.4)	102 (69.4)	
Overweight	95 (34.9)	31 (21.1)	
Obese	16 (5.9)	5 (3.4)	
BMD (g/cm^2)			
Lumbar spine			0.877
Range	0.680–1.713	0.561–1.476	
Mean (SD)	1.099 (0.199)	0.933 (0.196)	
Femoral neck			0.928
Range	0.531–1.323	0.422–1.172	
Mean (SD)	0.888 (0.142)	0.760 (0.144)	
Total hip			0.445
Range	0.546–1.460	0.503–1.235	
Mean (SD)	0.964 (0.156)	0.822 (0.151)	
33% radius			0.039
Range	0.550–1.188	0.486–1.050	
Mean (SD)	0.885 (0.095)	0.843 (0.118)	
Diagnostic categories, n (%)			<0.001*
Normal	131 (48.2)	25 (17.0)	
Osteopaenia	119 (43.8)	69 (46.9)	
Osteoporosis	22 (8.1)	53 (36.1)	

Body mass index (BMI) categories were defined as follows: underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9) and obese (BMI ≥30.0). Bone mineral density (BMD) was classified according to WHO criteria: normal (T-score ≥−1.0), osteopaenia (T-score <−1.0 to >−2.5) and osteoporosis (T-score ≤−2.5).
P value <0.05 were considered statistically significant based on independent t-tests.
*Indicates p values derived from X^2 tests.

Among the subset of 147 patients who had fractures, a total of 163 fragility fractures were identified. Vertebral fractures were the most prevalent, accounting for 63% of the cases. Hip fractures constituted 18% of the fractures, while other types of fractures and distal forearm fractures made up 10% and 9% of the cases, respectively.

The prevalence of fractures varied by BMI and fracture type. For overall fragility fractures, the prevalence was highest among underweight patients (69.2%), followed by normal weight (39.5%), overweight patients (24.6%) and obese (22.3%). Vertebral fractures were also most prevalent among underweight patients (61.5%), with lower rates observed in normal weight (27.1%), obese (22.7%) and overweight patients (15.1%). For the hip fracture, the highest prevalence was observed in underweight

Table 2 OR of fragility fractures at each site, comparing between different body mass index categories (n=419)

Fracture sites	BMI categories	Non-fracture (n)	Fracture (n)	OR*	95% CI		P value
					Lower	Upper	
Overall fragility fractures	Underweight	4	9	3.44	1.03	11.47	0.044
	Overweight	95	31	0.50	0.31	0.80	0.004
	Obese	16	5	0.45	0.16	1.26	0.128
Vertebral fracture	Underweight	5	8	4.30	1.36	13.58	0.013
	Overweight	107	19	0.48	0.27	0.84	0.010
	Obese	17	5	0.79	0.28	2.22	0.655
Hip fracture	Underweight	11	2	1.95	0.41	9.36	0.404
	Overweight	121	5	0.44	0.16	1.20	0.109
	Obese	21	1	0.51	0.07	3.98	0.521
Distal radius fracture	Underweight	12	1	2.99	0.34	26.27	0.324
	Overweight	119	7	2.11	0.72	6.15	0.172
	Obese	22	0	N/A	N/A	N/A	N/A
Other fragility fractures	Underweight	12	1	1.87	0.22	15.71	0.564
	Overweight	122	4	0.74	0.23	2.36	0.606
	Obese	22	0	N/A	N/A	N/A	N/A

*ORs were computed for dichotomous variables using logistic regression, with the reference group being patients with a normal BMI. The BMI was classified as follows: (1) underweight: BMI less than 18.5, (2) normal weight: BMI between 18.5 and 24.9, (3) overweight: BMI between 25.0 and 29.9 and (4) obese: BMI 30.0 and above.
BMI, body mass index.

patients (15.4%), followed by normal weight (8.5%), obese (4.5%) and overweight patients (4.0%). The distal forearm fractures were most common in underweight patient (7.7%), followed by overweight (5.6%) and normal weight patients (2.7%). Other fragility fractures were also more common in underweight (7.7%) and normal weight patients (4.3%) compared with overweight (3.2%). Notably, no distal forearm or other fragility fractures were observed among obese patients.

Our study revealed a significant variation in the risk of fragility fractures across different BMI categories. Patients in the underweight category were observed to have a substantially elevated risk, with an OR of 3.44 (95% CI: 1.03 to 11.47, p=0.044) for overall fragility fractures. In contrast, patients in the overweight category exhibited a reduced risk, with an OR of 0.50 (95% CI: 0.31 to 0.80, p=0.004). On focusing on vertebral fractures, a similar pattern was observed. Underweight patients again demonstrated a significantly higher risk (OR=4.30, 95% CI: 1.36 to 13.58, p=0.013), while overweight patients presented a lower risk (OR=0.48, 95% CI: 0.27 to 0.84, p=0.010). However, for hip fractures, distal forearm fractures and other fractures, the ORs did not show significant differences across the various BMI categories (table 2).

Spearman's correlation analysis revealed moderate positive correlations between BMI and BMD at the lumbar spine (r=0.607, p=0.028) and the 33% radius (r=0.557, p=0.084) among underweight patients. No statistically significant correlations were observed in the other BMI groups (figure 1).

DISCUSSION

This study investigated the relationship between BMI and the risk of fragility fractures in 419 Thai male patients, revealing significant associations between BMI categories and fracture risk. Underweight individuals exhibited a markedly higher risk of overall and vertebral fragility fractures, with ORs of 3.44 and 4.30, respectively. Conversely, overweight individuals demonstrated a protective effect against fractures, with ORs of 0.50 for overall fractures and 0.48 for vertebral fractures. The study also identified moderate positive correlations between BMI and BMD at the lumbar spine and 33% radius in underweight patients. These findings highlight the importance of BMI as a predictive marker for fracture risk and underscore the need for targeted interventions to improve bone health in underweight individuals.

BMI serves as a risk factor for fragility fractures in men

Our analysis reveals a significant correlation between a low BMI and an elevated chance of fragility fractures in underweight Asian men. Our finding is consistent with previous reports that have reported similar results in both combined male and female Asian populations[17–20] and in research that has analysed male and female patients separately.[6] In contrast, a prior meta-analysis reported no statistically significant association between low BMI and fracture susceptibility in men (RR, 1.50; 95% CI, 1.00 to 2.26; p=0.051).[2] This discrepancy may be attributable to differences in study populations: the meta-analysis included predominantly Western men (n=117 322), with

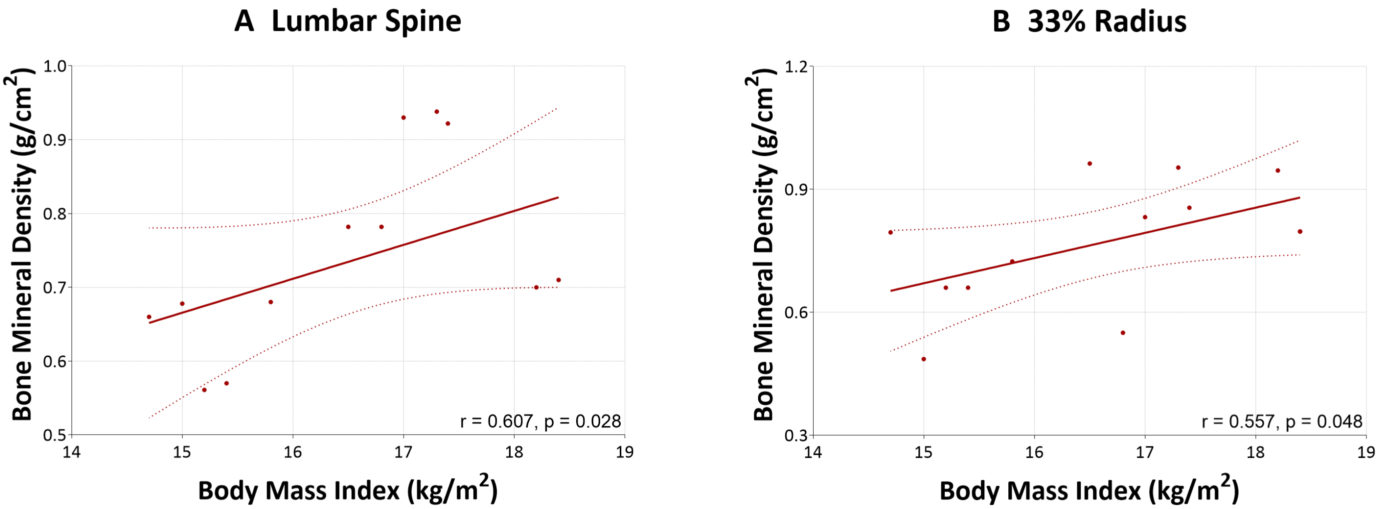

Figure 1 Spearman's correlation between BMI and BMD in underweight participants showed a moderate positive correlation at the lumbar spine (r=0.607, p=0.028) (A) and the 33% radius of the forearm (r=0.557, p=0.084) (B). BMD, bone mineral density; BMI, body mass index.

Asian participants representing only 0.8% of the total (n=1050) and limited to Japanese men with rheumatoid arthritis, a subgroup that may not reflect the general population.

Our findings, therefore, suggest that underweight Asian men may be at higher risk of fragility fractures compared with those with greater BMI. Unfortunately, there was no article that mentioned the risk of fragility in the underweight group in the Western population. This might be because there is a low number of underweight individuals in the Caucasian population.[21]

Regarding higher BMI, our study found that being overweight has a protective effect against fragility fracture in Asian men, which supports previous evidence that has reported similar findings in Asian populations.[20 22] There is limited information specifically on overweight and fragility fractures in Asian men, but previous literature across various population groups has also yielded comparable results, suggesting that higher BMI may reduce the risk of fractures.[2 4 23] However, some investigations suggest different results, stating that a higher BMI was not significantly correlated with the occurrence of fragility fractures in men.[9 24] These results may be due to these studies being performed mainly in the Caucasian population, with a small number of Asian populations included, which is only 0.5–2% of all population.

Location of fragility fractures in men

Our analysis identified the vertebrae as the most common site of fragility fractures in men, followed by the hip, other locations and the distal forearm. To our knowledge, only two publications have been conducted in underweight Asian men, both of which reported similar findings, indicating that vertebral fractures have the highest incidence in this population.[6 25] The hip[6] and limb[25] were found to be the second most common sites of fragility fractures.

A majority of articles have found a consistency in the location of these fractures among European populations.[26] However, a number of sources have indicated that the hip is the predominant site of fragility fractures in men, succeeded by vertebral fractures.[27–29] The higher incidence of vertebral fractures and lower incidence of hip fractures in Asian populations, as compared with Caucasian populations, is yet to be definitively explained. Potential reasons for the variation in the most frequent fracture site between Asian and European populations could be attributed to a multitude of factors, including genetic predispositions, nutritional habits, lifestyle choices and environmental influences, which may contribute to disparities in bone strength among different ethnicities.[1] These factors could influence the incidence of vertebral fractures, which are primarily dependent on bone strength.[30] Moreover, variations in femur size and hip geometry,[31 32] as well as cultural determinants of activity levels and fall risk, between Asian and Caucasian populations may also account for the observed differences in fracture incidence among these ethnicities.[33]

Correlation between a lower BMI and bone density value in underweight

In underweight men, we observed a significant positive correlation between BMI and BMD, particularly at the lumbar spine and 33% radius. This observation aligns with a previous report conducted in a Korean population, which suggested a positive correlation between BMD, BMI and weight.[34] Moreover, previous studies also found a positive association between BMI and BMD at the lumbar spine.[3 35] It has been suggested that a decline in BMD could potentially elevate the risk of clinical fragility fractures.[36 37] These findings underscore that individuals with a lower BMI, who are underweight, will have lower BMD and a higher susceptibility to fragility fractures. The implications of our findings are significant. Recognising BMI as a predictive indicator for fragility fractures could facilitate early detection and prevention strategies. Maintaining a healthy BMI through a balanced diet and regular exercise could potentially prevent fragility fractures in the Asian male population.

Protective mechanisms of overweight against fragility fractures

The mechanisms by which being overweight may protect against the presence of fragility fractures include several factors. Overweight individuals often exhibit higher BMD due to the increased mechanical loading on bones, which can enhance bone strength and reduce the risk of fractures.[38] Additionally, the extra adipose tissue in overweight individuals can provide a cushioning effect during falls, potentially mitigating the impact on bones and thereby lowering the risk of fractures.[4] Furthermore, adipose tissue produces hormones such as oestrogen, which can exert a protective effect on bone health by reducing bone resorption and maintaining bone density.[4] Moreover, overweight individuals may engage in weight-bearing activities that enhance muscle strength and balance, thereby reducing the likelihood of falls and subsequent fractures.[4]

Limitation and suggestion

As a retrospective study with a single-centre design, data quality could be an issue as some information may be missing. It was not possible to include all information of the patient at that time, which would have helped to establish a cause-and-effect relationship more precisely. Furthermore, as our research was conducted in a single tertiary care unit, the findings may not be generalisable to other populations. Owing to the inherent limitations of a retrospective study, we are unable to obtain essential historical data on factors influencing bone density, including exercise habits, tobacco use and alcohol consumption. Additionally, the small number of underweight participants may limit the interpretation of findings related to bone density in this subgroup.

Clinical implications

Our findings indicate that underweight Asian men with low BMI face a significantly increased risk of fragility fractures, underscoring the importance of early detection and the potential role of BMI as a predictive marker. The clinical implications of these findings are significant. Healthcare providers should consider BMI as a crucial factor in assessing fracture risk and developing preventive strategies. For underweight patients, public health interventions, including educational programmes, dietary guidelines and physical activity recommendations, could potentially prevent these fractures by maintaining a healthy BMI. Interventions aimed at increasing BMI and improving nutritional status may be beneficial in reducing fracture risk. Conversely, maintaining a healthy weight in overweight patients can help preserve bone health and prevent fractures.

Conclusions

The study underscores a significant risk of fragility fractures in underweight Asian males, identifying BMI as a potential predictor of fragility fracture risk, especially vertebral fracture. The study found a positive correlation between BMI and BMD, particularly in underweight patients. This suggests that early detection and public health interventions based on BMI could aid in fracture prevention. Therefore, future research should aim to confirm these findings in different settings. This would improve the quality of the data and help us better understand fracture risk across different demographics and BMI levels. Ultimately, this could lead to more effective strategies for preventing fractures.

Healthcare providers should consider BMI in assessing fracture risk and developing preventive strategies. Early detection and targeted interventions can improve bone health and reduce fragility fractures in the Asian male population.

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Patient consent for publication Not applicable.

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Provenance and peer review Not commissioned; externally peer reviewed.

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