Journal of Nutrition and Food Security
Shahid Sadoughi University of Medical Sciences
School of Public Health
Department of Nutrition
Nutrition & Food Security Research Center

eISSN: 2476-7425 pISSN: 2476-7417 JNFS 2023; 8(1): 9-16 Website: jnfs.ssu.ac.ir

Association between Body Mass Index, Abdominal Obesity, and Body Size with Hip and Femoral Fractures in the Elderly

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ARTICLE INFO

ORIGINAL ARTICLE

Article history:
Received: 22 Aug 2021
Revised: 20 Sep 2021
Accepted: 16 Oct 2021

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ABSTRACT

Background: The risk of bone fractures, particularly hip fractures is increasing in the elderly. One of the known factors for predicting fractures is body mass index (BMI) and abdominal obesity. Thus, this study aimed to determine the association between obesity (general and abdominal) with femoral and hip fractures according to gender and age. **Methods:** In this descriptive cross-sectional study, 100 patients with femoral or hip fractures admitted to the orthopedic ward of Khatam Al-Anbia Hospital in Zahedan were selected between March 2018 and May 2019. Waist circumference (WC), wrist circumference, BMI, and body size were measured. A P-value of <0.05 was considered as statistical significant. All the analyses were performed by SPSS software version 21. **Results:** The highest rate of hip fracture was observed in people aged over 70 years (61.9%, $P < 0.01$). The highest rate of hip and femoral fractures were observed in individuals with BMI < 23 kg/m^2 ($P < 0.001$) and taller people (>167 cm) ($P < 0.0001$). The risk of fractures decreased with increasing WC ($P < 0.01$). Approximately half of those with hip fractures (52.4%) and femoral fractures (51.9%) had small size. **Conclusion:** On the basis of our findings, taller height, lower BMI and smaller body size have been suggested as potential contributions to the risk of femoral and hip fractures. It is suggested that abdominal fat may be protective against the risk of hip and femoral fractures at older ages, which requires further research.

Keywords: *Body mass index; Abdominal obesity; Body size; Hip fracture; Femoral fracture*

Introduction

Given the increasing number of aging population worldwide, the prevalence of bone fractures is increasing. On the other hand, the prevalence of obesity, particularly among the elderly has increased over the past few decades, thus it is necessary to investigate the factors affecting fractures (Søgaard *et al.*, 2016). One of the known factors for predicting future fractures is

This paper should be cited as: Montazerifar F, Taghvaeefar R, Karajibani M, Izad Panahi B***. Association between Body Mass Index, Abdominal Obesity, and Body Size with Hip and Femoral Fractures in the Elderly.*** *Journal of Nutrition and Food Security (JNFS)*, 2023; 8 (1): 9-16.

body mass index (BMI) (Compston *et al.*, 2014). Epidemiological studies have shown that low BMI is a risk factor for fragility fractures (De Laet *et al.*, 2005, Johansson *et al.*, 2014). Low BMI is associated with low bone mineral density (BMD), less soft tissue, and muscle weakness, and may increase the risk of fractures (Nielson *et al.*, 2012). BMD, assessed by the absorption of dual energy x-rays (DXA), is an effective factor in predicting fracture risk. However, other risk factors including age, female gender, history of previous fractures, BMI, and comorbidities are also predictors of fracture risk (Adami *et al.*, 2013, Kanis *et al.*, 2011, Rossini *et al.*, 2016). It is evidence that total body weight is a beneficial predictor for the hip, femur, and rib fractures when BMD has not been measured (Margolis *et al.*, 2000).

Hip fracture is the one of the most common osteoporotic fractures in the elderly, which is associated with disability and functional impairment. It is estimated that 1.6 million hip fractures occur worldwide each year (Majumdar *et al.*, 2017) and 12-58% of the elderly die within a year after a hip fracture and the mortality rate increases (Panula *et al.*, 2011). Hip fracture is a fracture of the femur that occurs between the hip joint and below the distal point of the lesser trochanter. The femoral head is part of the complex structures of the hip. It is estimated that 4-17% of posterior hip fractures are related to femoral head (Edem *et al.*, 2018).

Obese older people are less at risk for some fractures, including pelvic, spinal, and wrist fractures, due to their higher BMD and softer tissue that absorbs the shock (Compston, 2013). However, 50% of hip fractures occur in older men and women who are overweight or obese (Nielson *et al.*, 2012). Some factors associated with obesity that potentially increase the risk of fractures include low physical activity, vitamin D deficiency, hypogonadism, and diseases associated with obesity, such as diabetes mellitus (Compston, 2013).

Abdominal obesity has also been implicated as a protective factor for hip fractures. Prospective studies have shown conflicting results regarding the association between abdominal obesity and hip fractures (Sadeghi *et al.*, 2017, Tang *et al.*, 2013). According to the contradictory results reported on the effect of BMI and abdominal obesity on the risk of fractures, this study was conducted to investigate the relationship between anthropometric indices including BMI (as general obesity) and waist circumference (as abdominal obesity) with femoral and hip fractures.

Material and Methods

Study design and participants: In this cross-sectional study, 100 patients aged over 50 years (55 males and 45 females) with femoral or hip fractures admitted to the orthopedic ward of Khatam Al-Anbia Hospital affiliated with Zahedan University of Medical Sciences, Zahedan, Iran, were selected between March 2018 and May 2019. The patients were selected through convenience sampling method.

Male patients older than 50 years and female patients aged 60 years were enrolled in this study. The exclusion criteria included pregnancy, lactation, kidney failure, advanced liver failure, cancer, chronic diarrhea (more than 2 weeks), malnutrition, bed rest for 3 consecutive months, history of hospitalization during the last 2 weeks, patients with any defect in the spine, pelvis and lower limbs, accidental fractures, weight > 120 kg and incomplete demographic data or radiographs.

Measurements: To measure weight, because patients could not stand, the following formula was used to calculate weight (Mahan and Raymond, 2016):

Females: (2.68 * middle arm size) + (1.09 * knee height) -65/51

Males: (3.07 * middle arm size) + (1.1 * knee height) -75/81

Knee height was used to measure height in the hospitalized patients:

Height in women: 84 / 88- (0.24 * Age) + (1.83 * Knee height)

Height in men: 64 / 19- (0.04 * age) + (2.02 * knee height).

Then BMI was calculated by dividing weight (kg) to height squared (m^2) (Mahan and Raymond,

[DOR: 20.1001.1.24767417.2023.8.1.2.8]

[DOI: 10.18502/jnfs.v8i1.11760]

2016) . The patients were statistically classified based on the following parameters: BMI (< 23 kg/m^2 and > 23 kg/m^2), age (50-70 and > 70 years), weight (< 57 and > 57 kg), height (< 167 and > 167 cm) (Edem *et al.*, 2018), and type of fracture (hip and femur).

To determine the body size, the wrist circumference was measured and the body size was determined by dividing the height by the wrist circumference. The ratios; r > 10.4 and r < 9.6 in men, and r > 11 and r < 10.1 in women were considered small and large size, respectively.

To assess abdominal obesity, waist circumstance (WC) was measured using a non-elastic tape at the narrowest point between the lower edge of the rib and the upper iliac crest. WC > 102 cm in men and WC > 88 cm in women was considered as abdominal obesity (Mahan and Raymond, 2016).

An orthopedic specialist confirmed hip and femoral fractures by X-ray and personal interview.

Ethical considerations: This study was approved by the Ethics Committee of Zahedan University of Medical Sciences (No: 2234; 7 Jan 2018).

Data analysis: The data were analyzed by SPSS software version 21 (SPSS, Inc. Chicago IL, USA) and were presented as mean ± standard deviation (SD) and frequency (%). The Student's *t-test* and Chi-square *test* were used to compare the quantitative variables and categorical variables, respectively. Pearson correlation coefficient was used to determine associations between continuous variables. A P-value of < 0.05 was considered as statistical significant.

Results

In the present study, 100 patients (55 males and 45 females with mean age of 71.78 ± 11.59 years) were studied. The minimum and maximum age was 50 and 97 years. The mean BMI and waist circumference in the patients with hip and femoral fractures were 25.18 ± 2.01 kg/m^2 and 24.55 ± 2.60 kg/m^2, and 91.04 ± 9.87 cm and 89.06 ± 10.62 cm, respectively. The mean body size was 9.83 ± 1.02 in patients with hip fracture and 9.80 ± 1.04 in those who had femoral fracture. The data demonstrates that taller patients ($P < 0.05$) particularly the men more suffered from hip and femoral fractures (**Table 1**).

Table 2 shows that there was no significant relationship between both sexes with the risk of hip and femur fractures (both, $P > 0.05$). The highest rate of hip fracture was observed in people aged over 70 years (61.9%, $P < 0.01$) in both men and women, whereas there was no significant difference between two age groups and risk of femoral fracture ($P = 0.10$). The highest rate of hip and femoral fractures was observed in weight > 57 kg (81%, $P < 0.0001$ and 82.3%, $P < 0.0001$, respectively), height >167 cm (76.2%, $P < 0.0001$ and 70.9%, $P < 0.0001$, respectively), and BMI < 23 kg/m^2 (85.7%; $P < 0.001$ and 81%; $P < 0.001$). The hip and femoral fractures rate in patients with abdominal obesity was significantly less than those with normal waist circumference (33.3% *vs* 66.7%, $P < 0.01$ and 38% vs 62%, $P < 0.01$, respectively). Approximately half of the participants with hip fractures (52.4%) and femur fractures (51.9%) were small size.

The results showed that age was negatively correlated with height (r = -0.57, $P = 0.007$) and BMI (r = -0.71, $P = 0.04$) in patients with hip fracture. A negative correlation was also found between age and BMI (r = -0.79, $P = 0.03$) in those who had femoral fracture. The data showed no correlation between the type of fractures in terms of other studied parameters (WC, body size, and gender, **Table 3**).

Table 1. Comparison of mean of variables of the patients based on the type of fracture and sex.

Variables	Type of fracture: Hip (n=21) Male	Hip (n=21) Female	P-value[a]	Femur (n=79) Male	Femur (n=79) Female	P-value[a]
Age (year)	72.58 ± 10.65[b]	73.67 ± 9.42	0.51	71.69 ± 8.11	71.05 ± 7.76	0.56
Weight (kg)	68.83 ± 9.26	62.21 ± 3.50	0.05	67.38 ± 8.91	62.10 ± 4.62	0.06
Height (cm)	169.74 ± 8.23	157.53 ± 4.81	0.04	168.48 ± 7.62	157.43 ± 3.89	0.03
BMI(kg/m^2)	25.57 ± 2.15	24.90 ± 1.94	0.68	25.01 ± 2.89	24.15 ± 2.29	0.59
WC (cm)	96.94 ± 8.56	83.17 ± 4.60	0.06	94.21 ± 11.27	82.91 ± 8.78	0.07
Body size	9.46 ± 0. 96	10.32 ± 0.91	0.98	9.45 ± 0.78	10.22 ± 1.16	0.37

[a]: Student *t-test*, [b]: Mean ± SD, BMI: Body mass index, WC: Waist circumference.

Table 2. Statistical assessment of BMI, abdominal obesity, body size, age, and sex in the patients based on the type of fracture

Variables	Type of fracture: Hip (n=21)	P-value[a]	Femur (n=79)	P-value[a]
Gender				
Male	11 (52.4)[b]	0.33	43 (54.4)	0.43
Female	10 (47.6)		36 (45.6)	
Age (year)				
50-70	8 (38.1)	0.01	42 (53.2)	0.10
70-97	13 (61.9)		37 (46.8)	
Weight (kg)				
< 57	4 (19.0)	0.0001	14 (17.7)	0.0001
> 57	17 (81.0)		65 (82.3)	
Height (cm)				
< 167	5 (23.8)	0.0001	23 (29.1)	0.0001
> 167	16 (76.2)		56 (70.9)	
Body mass index (kg/m^2)				
< 23	18 (85.7)	0.001	64 (81.0)	0.001
> 23	3 (14.3)		15 (19.0)	
Abdominal obesity				
Yes	7 (33.3)	0.01	30 (38.0)	0.01
No	14 (66.7)		49 (62.0)	
Body size				
Small	11 (52.4)	0.001	41 (51.9)	0.001
Normal	7 (33.3)		23 (29.1)	
Large	3 (14.3)		15 (19.0)	

[a]: Chi square test, [b]: n (%)

[DOR: 20.1001.1.24767417.2023.8.1.2.8]

[DOI: 10.18502/jnfs.v8i1.11760]

Table 3. Correlation between age and anthropometric parameters in the patients based on the type of fracture.

Variables		Type of fracture	
		Hip (n=11)	Femur (n=79)
Weight (kg)	r	0.412	0.146
	P-value	0.064	0.101
Height (cm)	r	-0.571	-0.200
	P-value	0.007	0.078
Body mass index (kg/m^2)	r	-0.710	-0.796
	P-value	0.040	0.030
Waist circumference (cm)	r	0.416	0.200
	P-value	0.187	0.078
Body size	r	-0.335	-0.455
	P-value	0.138	0.085

Discussion

Anthropometric indices are identified as the useful parameters for assessing health and identifying people at risk (Mahan and Raymond, 2016) . In this study the association of age, gender, height, weight, BMI, and WC was assessed on patients with hip and femoral fractures.

The results revealed that taller patients with BMI less than 23 kg/m^2 were more likely to have hip and femoral fractures. Studies have reported the possible relationship between BMI and the risk of hip fracture. Some reviews and meta-analysis studies have reported that high BMI, as a general obesity index, protectively decreases the risk of hip fracture (Armstrong *et al.*, 2011, Benetou *et al.*, 2011, Sadeghi *et al.*, 2017). However, some studies have suggested that overweight or obesity does not decrease the hip fracture risk compared to normal weight (Compston *et al.*, 2011, Nielson *et al.*, 2011, Scott *et al.*, 2020). Some studies revealed that overweight/obese individuals are at high risk of fracture (Compston, 2013, Gower and Casazza, 2013). A study reported that people with a BMI < 20 kg/m^2 had a significant increase in the risk of proximal femoral fractures (Nielson *et al.*, 2011). Low BMI is associated with reduction in mineralization density (De Laet *et al.*, 2005, Johansson *et al.*, 2014, Nielson *et al.*, 2012), less soft tissue and muscle weakness, and may increase the risk of fractures (Nielson *et al.*, 2012).

In addition, the effect of body height on fracture risk has also been intensively studied. Several epidemiological studies have reported that height is associated with increased risk of hip fracture (Bjørnerem *et al.*, 2013, Leslie *et al.*, 2014, Xiao *et al.*, 2016). The current study showed that the risk of femoral and hip fractures was higher in taller patients particularly in males. It has been demonstrated that taller people more suffer from hip and femoral fractures, although wider bones better withstand flexion. Because wider bones need less material to achieve a certain flexural strength (Bjørnerem *et al.*, 2013); however, a study has failed to confirm this result (Leslie *et al.*, 2014). A study reported that hip fracture affects gender (Xiao *et al.*, 2016). The association between gender and height and the risk of fractures need to be further investigated.

Body weight consists of lean and fat mass and the role of each component in the risk of fracture is different. The type of obesity plays a vital role in the hip fracture risk. Central abdominal obesity, which is associated with abdominal and thoracic distributions of adipose tissue (Irving *et al.*, 2019), is directly linked to BMD and low risk of fracture (Ho-Pham *et al.*, 2010). Interestingly, the present study show that those who had abdominal obesity (based on WC) and weight gain (> 57 kg) seemed to have a much lower fracture risk, suggesting that abdominal fat is likely identified as a protective parameter against hip and femoral fractures risk at older ages, regardless of general obesity status (Scott *et al.*, 2020).

Overall, conflicting data have been reported about the association between abdominal obesity and hip and femoral fractures. In line with the present study, an inverse relationship was found between WC and the risk of hip fractures in some previous studies (Irving *et al.*, 2019, Kauppi *et al.*, 2014). However, the findings of several studies have revealed that hip fractures were more common in obese people (Irving *et al.*, 2019, Kanis *et al.*, 2011, Sadeghi *et al.*, 2017). Another study reported that abdominal obesity was not associated to the risk of hip fracture (Benetou *et al.*, 2011).

The role of fat tissue in fracture risk is not yet well understood and there is controversy about the protective effect of abdominal obesity on fracture risk. The mechanism by which overweight and obesity protect against the risk of fracture may be related to higher BMD and more shock absorption than additional soft tissue (Leslie *et al.*, 2014, Scott *et al.*, 2020). There are other mechanisms that may make these people prone to fractures such as increased central fat and changes in insulin homeostasis in obese people, low physical activity and comorbidities (Compston, 2013), as well as vitamin D deficiency, adipose tissue cytokines, excessive force on the bone due to weight gain and muscle strength (Amati *et al.*, 2012, Barbour *et al.*, 2011). Other studies have reported that obese people with increased visceral adipose tissue have poorer bone compared to those with low visceral adipose tissue (Yi *et al.*, 2016).

The association between weight, height, BMI and body fat mass with fracture is complicate and varies with age and fracture location (Gower and Casazza, 2013).

The results of the present study showed that most of the patients were in the age group of 70-97 year, and the hip fracture was more common among this age group. However, no association was found between this parameter with femoral fracture. A meta-analysis has demonstrated an inverse correlation (Mayhew *et al.*, 2005) and another study found no association between age and femoral fracture (Edem *et al.*, 2018). The risk of fractures was not significantly different between both sexes, but the highest rate of hip fracture was observed among patients aged 70-97 years with a BMI < 23 kg/m^2 (data not shown). There was a significant negative correlation between age and height and BMI in patients with hip fracture, and also between age and BMI in those who had femoral fracture. This would suggest that a low BMI is very important for hip and femoral fractures, which are independent of sex, but dependent on age.

The association between age and hip fracture, apart from accidents and decreased BMD, may be partly related to increased total body fat and decreased physical activity (Benetou *et al.*, 2011, Edem *et al.*, 2018, Scott *et al.*, 2020, Xiao *et al.*, 2016), which was not investigated in the current study.

The present study found no significant correlation between other studied parameters with hip and femoral fractures, which might be because of the small sample size in this study.

In addition to the above parameters, the effect of body size on fracture risk has also been investigated in the present study. The findings demonstrated that patients with smaller body size might have higher risk of hip and femoral fractures compared to those with larger body size. This effect may be due to a decrease in BMD in women with smaller body size (Ensrud *et al.*, 1997). There are limited and contradictory data in this regard. A study in line with the present study found that women with smaller body size were at higher risk for hip fracture (Ensrud *et al.*, 1997). However, a cohort study reported that smaller body size was not identified as a risk factor for fractures of elbow, wrist ankle, or foot (Margolis *et al.*, 2000).

The strength of the study was the identification of at risk population with the simplest tools.The study also had numerous limitations, including 1) The participants aged 50 years and over, so it is not generalizable to young people; 2) The authors were unable to assess the effect of body composition and physical activity on fracture risk; 3) Total body fat, body fat percentage, and waist-to-hip ratio (WHR), which may have a stronger predictive value were not measured; 4) Due to the small sample size, a moderate reduction in risk may be detected; and 5) The authors could not

[DOR: 20.1001.1.24767417.2023.8.1.2.8]

[DOI: 10.18502/jnfs.v8i1.11760]

measure BMD, which have a key role in hip and femoral fractures.

Conclusion

According to the findings, taller height, lower BMI, and smaller body size have been suggested as potential contributions to the risk of femoral and hip fractures. It is suggested that abdominal fat may be a protective against the risk of hip and femoral fractures at older ages, which requires further research.

Acknowledgment

This study is extracted from a medical student thesis and was supported by the Research Vice Chancellor of Zahedan University of Medical Science, Zahedan, Iran (number: 2234, Approval date: Jan. 2018). Thanks are owed to Arash Ghaffari "Orthopedic specialist" for visiting patients, Ali Reza Dashipour for his guidance in statistical analysis, and all the patients who participated in this study.

Competing interest

The authors declare no competing interest.

Authors' contributions

Montazerifar F and Karajibani M designed the study; Montazerifar F and Taghvaeefar R wrote the paper, Izad Panahi B contributed data collection; Montazerifar F analyzed the data; Montazerifar F, Taghvaeefar R, and Karajibani M interpreted the results. All authors read and approved the final manuscript.

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[DOR: 20.1001.1.24767417.2023.8.1.2.8]

[DOI: 10.18502/jnfs.v8i1.11760]