CAPÍTULO 4

BODY MASS INDEX FOUND NOT TO BE ASSOCIATED WITH METABOLIC INDICATORS IN PATIENTS WITH ORTHOPEDIC TRAUMA

Hallan Douglas Bertelli

Ms, Postgraduate Program in Health Science, Puc-Campinas-SP-Brazil

Vânia Aparecida Leandro-Merhi

PhD, Professor Doctor of the Postgraduate Program in Health Sciences, Puc-Campinas-SP-Brazil

José Luis Braga de Aquino

PhD, Professor Doctor of the Postgraduate Program in Health Sciences, Puc-Campinas-SP-Brazil

Carla Adriane Roballo Bertelli

Professor at the Faculty of Medicine, Puc-Campinas, SP-Brazil

Kelly Cristine Santos Roballo

University of Wyoming, School of Pharmacy, USA

ABSTRACT: **Introduction**: The relevance of the nutritional status in patients with orthopedic trauma (OT) has been enhanced in the literature. **Objective**: This study compared overweight and obese pa- tients with normal body weight patients and their relationship with nutritional and metabolic indicators. **Methods**: Patients with OT (n=108) were investigated in a prospective study for body mass index (BMI) in relation to their calf circumference (CC), vitamin D and albumin serum levels. The statistical analysis included the Chi-square or Fisher tests and the Mann-Whitney test and Spearman's linear cor- relation coefficient. **Results**: There was no association between gender, type of fractured bone, laterality, smoking, diabetes, menopause, albumin and vitamin D and the two groups of patients classified by BMI. There was an association (p <0.0001) only with CC, with lower CC values in patients with normal body weight. **Conclusion**: BMI was not associated with metabolic indi- cators in patients with OT.

KEYWORDS: Orthopedic trauma, body weight, body mass index, vitamin D and albumin.

SE ENCONTRÓ QUE EL ÍNDICE DE MASA CORPORAL NO SE ASOCIA CON INDICADORES METABÓLICOS EN PACIENTES CON TRAUMATISMO ORTOPÉDICO

RESUMEN: **Introducción**: La relevancia del estado nutricional en pa- cientes con traumatismo ortopédico (TO) se ha reforzado en la literatura. **Objetivo**: Este estudio comparó pacientes con sobrepeso y obesidad con pacientes con peso corporal normal y su rela- ción con indicadores nutricionales y metabólicos. **Métodos**: Los pacientes con TO (n = 108) fueron investi- gados en un estudio prospectivo para el índice de masa cor- poral (IMC) en relación con su circunferencia de la pantorrilla (CC), vitamina D y niveles séricos de albúmina. El análisis es- tadístico incluyó las pruebas de Chi-cuadrado o Fisher y la prueba

de Mann-Whitney y el coeficiente de correlación lineal de Spearman. **Resultados**: No hubo asociación entre sexo, tipo de fractura ósea, lateralidad, tabaquismo, diabetes, menopausia, albúmina y vitamina D y los dos grupos de pacientes clasificados por IMC. Hubo asociación (p <0,0001) solo con CC, con valores de CC más bajos en pacientes con peso corporal normal. **Conclusión**: El IMC no se asoció con indicadores metabó- licos en pacientes con TO. **PALABRAS CLAVE**: Trauma ortopédico, peso corporal, índice de masa corporal, vitamina D y albúmina.

INTRODUCTION

Nutritional status, obesity, malnutrition, hypovitaminosis, cardiovascular diseases and diabetes, osteoporosis, among others, have been recognized as risk factors for increased in- cidence of orthopedic trauma (OT)[1]. In addition, in the inves- tigation of the study population nutritional status, the preva- lence of reduced vitamin D serum levels in fractured patients was observed[8]. A cross-sectional study involving patients with fractures showed that increased sun exposure, alcohol con- sumption and the use of vitamin D were considered to be in- dependent protective factors against severe vitamin D defi- ciency[5]. In the same study, it was also observed in a univariate analysis that male gender, older age, body mass in- dex (BMI) ≥30, among others, were potential risk factors for vitamin D deficiency[5]. Other studies also point out that the risk of certain fractures is higher in obese people and that a significant number of fractures can occur in those subjects[23].

An investigation conducted in China[11] revealed an average age of 45.4 years at the time of the fracture. Fracture history, average sleep time (less than 7 hours a day) and alcohol con- sumption were identified as independent risk factors for foot fractures in men and women. In the study in question, BMI> 24 kg/m^2 in women was also detected as being a risk factor[11]. In view of these considerations, the use of BMI could con- tribute to a better monitoring in the care of patients with or- thopedic trauma.

Thus, this study aimed to compare overweight and obese patients with normal body weight patients, and their relation- ship with nutritional and metabolic indicators.

METHOD

A prospective study was carried out in an orthopedics out- patient clinic of a hospital attending adult patients with foot and ankle fractures (n=108). The investigation was approved by the Institution's Ethics and Research Committee after the patients signed a free and informed consent form (FICF). According to the study design, adults of both genders with a previous fracture diagnosis of certain bones of the foot and/or ankle were included. Patients who did not accept to participate in the study, who were under the age of 18 years and those who were undergoing vitamin D replacement therapy, were excluded from the study. At the beginning of this inves- tigation, a clinical anamnesis and

an orthopedic physical ex- amination were performed, with confirmation of foot or ankle fractures by simple radiography performed in the study hos- pital. Laboratory and nutritional status assessments were per- formed after fractures were confirmed and before the treat- ment was started. Demographic data, comorbidities, type of fractured bone, anthropometric indicators and laboratory tests were investigated.

The anthropometric indicators evaluated were body weight, height, body mass index (BMI) and calf circumference (CC). The BMI for individuals up to 65 years of age, was set ac- cording the World Health Organization criteria[25] and for indi- viduals over 65 years of age, according to the Pan American Health Organization criteria[16]. Both Organizations classify pa- tients as underweight, normal weight, overweight and obese[16,25]. The European Sarcopenia Consensus criteria[2] were considered for the classification of CC (<34 cm for men and <33 for women).

Biochemical tests for serum albumin and vitamin D were performed. Albumin levels were classified as[17]:- severe de- pletion: <2.4mg/dl; moderate depletion: 2.4 - 2.9mg/dl; mild depletion: 3.0 - 3.5mg/dl and normal:> 3.5mg/dl.

Vitamin D was classified and analyzed according to two classifications (2014 and 2018) of the Sociedade Brasileira de Endocrinologia (SBE, Brazilian Society of Endocrinology). According to the 2014 SBE classification[7,12,15], the vitamin D serum dosage was considered as:- normal (≥30 ng/dL), in- sufficient (20-29 ng/dL) and deficient (<20 ng/dL). According to the 2018 SBE[3], the vitamin D serum dosage was consid- ered as:- normal for a healthy population up to 60 years of age (> 20 ng/dL), normal for risk groups and individuals over 60 years of age (≥30 ng/dL) and deficient (<20 ng/dl). For analysis purpose, the two vitamin D classifications and their relationship with the BMI were considered in this study.

Subsequently, for the analysis and comparison of the vari- ables assessed, the patients were divided into two groups, ac- cording to the BMI classification: overweight plus obese pa- tients (BMI above the reference line) and patients with normal body weight (BMI below the reference line).

In the statistical analysis, comparing proportions, the Chi- square test or Fisher's exact test were used when necessary, and the Mann-Whitney test was used to compare continuous measurements between the two groups. Spearman's linear correlation coefficient was used to investigate the relationship between BMI and the study variables of interest. The correla- tion coefficient can vary from -1 (indicating a strong negative correlation between the two variables) to 1 (indicating a strong positive correlation between the two variables). Values close to zero did not indicate a linear correlation between the two variables. The level of significance adopted for the statis- tical tests was 5%.

RESULTS

The studied population was composed of 108 patients, comprising 30.6% (n=33)

men and 69.4% (n=75) women; mean age was 50.5 ± 15.9 years. According to the BMI clas- sification, 67.59% (n=73) were overweight and obese and 32.40% (n=35) had normal body weight.

Table 1 shows the characteristics of the population and the comparison of the variables studied between the two groups of patients classified according to the BMI (overweight plus obesity and with normal body weight). There was no signifi- cant difference between the variables (gender, type of frac- tured bone, laterality, smoking, diabetes, menopause) and the two groups of patients.

When comparing the variables between the two groups of patients classified according to the BMI (Table 2), a significant association (p<0.0001) was found only with CC, with lower mean values (32.8 ± 1.8 cm) and median values (33.0 cm) of CC in patients with normal body weight. Table 3 also shows a significant association between BMI and CC.

Variables	Overweight plus obesity*(n=73)		Normal body weight* (n=35)		Total (n=108)		P-value
	n	%	n	%	n	%	
Gender							
Female	51	69.9	24	68.6	75	69.4	0.8915[2]
Male	22	30.1	11	31.4	33	30.6	
Fractured Bone							
Foot	34	46.6	18	51.4	52	48.1	0.6366[2]
Ankle	39	53.4	17	48.6	56	51.9	
Side							
Bilateral	2	2.7	0	0.0	2	1.9	0.6143[2]
Right	41	56.2	22	62.9	63	58.3	
Left	30	41.1	13	37.1	43	39.8	
Smoking							
No	67	91.8	32	91.4	99	91.7	1.0000[3]
Yes	6	8.2	3	8.6	9	8.3	
Diabetic							
No	60	82.2	32	91.4	92	85.2	0.2060[2]
Yes	13	17.8	3	8.6	16	14.8	
Menopause							
No	23	45.1	9	37.5	32	42.7	0.5349[2]
Yes	28	54.9	15	62.5	43	57.3	

*Weight classification by body mass index.

[2] Chi-square test; [3] Fisher's exact test.

Table 1. Characteristics of the studied population and comparison between the two groups of patients (overweight plus obesity and with normal body weight) (n=108)

Variables		Overweight plus obesity*(n=73)	Normal body weight*(n=35)	Total (n=108)	P-value
Age (years)	X±SD	50.4 ± 14.2	50.9 ± 19.4	50.5 ± 15.9	0.8464[1]
	median	53.0	48.0	52.5	
CC (cm)	X± SD	35.5 ± 2.5	32.8 ± 1.8	34.6 ± 2.6	<0.0001[1]
	median	35.0	33.0	34.0	
Vitamin D (ng/dl)	X± SD	25.8 ± 8.4	26.9 ± 9.1	26.2 ± 8.6	0.4151[1]
	median	26.0	27.0	27.0	
Albumin (mg/dl)	X± SD	4.2 ± 0.4	4.3 ± 0.4	4.2 ± 0.4	0.6381[1]
	median	4.2	4.3	4.2	

*Weight classification by body mass index.

[1] Mann-Whitney Test; CC: Calf Circumference.

Table 2. Comparison between the variables studied and the two groups of patients (overweight plus obesity and with normal body weight) (n=108)

Variables (%)	Overweight plus obesity*(n=73)		Normal body weight*(n=35)		Total (n=108)		P-value
	n	%	n	%	n	%	
Calf Circumference							
Reduction of muscle mass	7	9.6	17	48.6	24	22.2	<.0001[2]
No reduction	66	90.4	18	51.4	84	77.8	

*Weight classification by body mass index.

[2] Chi-Square Test.

Table 3. Association between body mass index and calf circumference

There was no significant association between BMI and vi-tamin D and albumin found in the laboratory exams (Table 4).

The correlation data analyzed in this study showed that there was a significant correlation only between BMI and CC. There was no linear correlation between BMI and vitamin D, albumin and age (Table 5).

DISCUSSION

Factors such as nutritional status and BMI have been asso-ciated with a predisposition to fractures, as well as other clin-ical situations such as cardiovascular diseases and diabetes, obesity, malnutrition, osteoporosis and hypovitaminosis[1].

In the present investigation, in the assessment of nutri- tional and metabolic indicators and their relationship with body weight in patients with foot and ankle fractures, no as- sociation between body weight, gender, age, vitamin D, albu- min and other variables assessed was found among the two groups of patients classified according to the BMI criteria (overweight plus obesity and normal body weight). Only the CC was associated with BMI, and patients with normal body weight exhibited smaller CC values compared to the values of overweight and obese patients. Findings different from this investigation were observed in a retrospective study that in- vestigated an association between obesity and severity of an- kle fractures, showing that being obese was associated with a greater risk of suffering more severe ankle fractures, espe- cially in the case of obese men under 25 and obese women over 50 years of age. [10] Another study pointed out that a higher BMI resulted in a greater tendency to see ankle frac- tures, specifically in the fibula in men and bimalleolar and tri- malleolar in women[20].

A work recently developed by Gkastaris et al., 2020[4], in- vestigated the association of osteoporosis and bone metabo- lism. The authors suggested that obesity could have a nega- tive impact on bone health, since low-grade systemic inflammation would likely to be harmful to bones due to the positive regulation of pro-inflammatory cytokines and the in- creased leptin production observed in obese patients[4].

Variables	Overweight plus obesity*(n=73)		Normal body weight*(n=35)		Total (n=108)		P-value
	n	%	n	%	n	%	
Albumin							
Moderate depletion	1	1.4	0	0.0	1	0.9	-
Mild depletion	2	2.7	2	5.7	4	3.7	
Normal	70	95.9	33	94.3	103	95.4	
Albumin							
Mild and moderate depletion	3	4.1	2	5.7	5	4.6	0.6582³
Normal	70	95.9	33	94.3	103	95.4	
Vitamin D*							
Deficiency	18	24.7	8	22.9	26	24.1	0.7644²
Insufficiency	33	45.2	14	40.0	47	43.5	
Normal	22	30.1	13	37.1	35	32.4	
Vitamin D**							
≤30 (ng/dl)	51	69.9	22	62.9	73	67.6	0.4666²
>30 (ng/dl)	22	30.1	13	37.1	35	32.4	

Vitamin D***							
<20 (ng/dl)	18	24.7	8	22.9	26	24.1	0.8377[2]
≥20 (ng/dl)	55	75.3	27	77.1	82	75.9	

*Weight classification by body mass index.

[2] Chi-square Test; [3] Fisher's Exact Test.

Source: * Sociedade Brasileira de Endocrinologia (Brazilian Society of Endocrinology) (Maeda et al, 2014 [19]) and Holick et al., 2011 [20]. ** Sociedade Brasileira de Endocrinologia (Maeda et al, 2014 [19]) and Holick et al. 2011 [20], unifying disability and insufficiency.

*** Sociedade Brasileira de Endocrinologia (Ferreira et al., 2018 [22]).

Table 4. Association between the Body Mass Index and laboratory tests

Variables	Coefficient (r) *	P value
BMI vs. age	0.14966	0.1221
BMI vs. calf circumference	0.56516*	<.0001*
BMI vs. vitamin D	-0.15352	0.1127
BMI vs. albumin	-0.14559	0.1327

BMI: Body Mass Index. * Spearman's correlation coefficient, * p<0.05.

Table 5. Correlation between BMI and age, CP, vitamin D and al- bumin (n=108)

There are studies showing a strong correlation between BMI and lower limb fractures, associating the excessive in- crease in body mass with a greater energy transferred to the extremities, which could potentially lead to a fracture[18]. And fractures considered to be of low energy tend to be more se- vere in obese individuals[18].

Other studies have pointed out that obesity, especially the growth of android fat mass, is strongly associated with pain and the inability to move the feet and the biomechanical and metabolic mechanisms[21] and a high BMI associated with ag- ing, could also contribute to decreased functionality of the an- kle and foot joint[13].

It is also important to highlight the relationship between vi- tamin D dosages and obesity. It is known that a BMI greater than 30 kg/m^2 could influence vitamin D plasma levels[26, 24], probably due to the solubility of vitamin D in lipid compounds, such as the adipose tissue, reducing its serum quantity and increasing its tissue accumulation[26].

Other investigations have also pointed out an association between vitamin D deficiency and OT, such as, for example, a recent study carried out with 617 patients reporting 40% of patients with vitamin D deficiency, with 11% of the patients having severe deficiency[6]. Another study, however with a smaller sample, showed 47% of patients with vitamin D defi- ciency and 11% with severe deficiency, with fractures of the foot and ankle[19].

Nutritional status is also another potential risk factor for fractures. A study of 1,055 fractured patients evaluated at different orthopedic institutes in Germany found that 19.5%

of them were malnourished[9]. In a study conducted in China, the authors investigated the causes of the high incidence of foot and ankle fractures in the general population and found that BMI> $24kg/m^2$ in women was a risk factor[11]. Low serum albumin concentration in conjunction with vitamin D defi- ciency may also be related to post-fracture and postoperative complications in orthopedic patients, such as pseudoarthro- sis and infections, as observed in other studies in the rele- vant literature[17,14,22].

The population studied here who enjoyed better purchas- ing power and the private hospital, where this study was con- ducted, can be considered as the main limiting factors of this investigation. It is suggested that further studies be carried out in patients with OT, in other institutions to better under- stand these findings.

CONCLUSION

BMI was not found to be associated with metabolic indica- tors in patients with OT.

REFERENCES

1. Acosta-Olivo C, Tamez-Mata Y, Elizondo-Rodriguez J, Rodriguez- Torres R, Diaz-Valadez A, Peña-Martinez V. Investigation of the association between the acute ankle injury caused by fall from own height and body mass index. J Foot Ankle Surg 2019; 58(2):288-90.

2. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F et al. Sarcopenia: European Consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Agein 2010; 39(4):412-23. Available from: http://www.ncbi.nlm.nih.gov\pmc\articles\PMC2886201.

3. Ferreira CES, Maeda SS, Batista MC, Lazaretti-Castro M, Vas- concellos, Miguel Madeira LS, Soares LM et al. Posicionamento Oficial da Sociedade Brasileira de Patologia Clínica/Medicina Laboratorial (SBPC/ML) e da Sociedade Brasileira de Endo- crinologia e Metabologia (SBEM) – Intervalos de Referência da Vitamina D - 25(OH)D. Arq Bras Endocrinol Meta 2018; 53(6): 377-81.

4. Gkastaris K, Goulis DG, Potoupnis M, Anastasilakis AD, Kapetanos

G. Obesity, osteoporosis and bone metabolism. J Musculoskelet Neuronal Interact 2020; 20(3):372-381.

5. Gorter EA, Krijnen P, Schipper IB. Vitamin D deficiency in adult fracture patients: prevalence and risk factors. Eur J Trauma Emerg Surg 2016; 42(3):369-378.

6. Gorter EA, Krijnen P, Schipper IB. Vitamin D status and adult frac- ture healing. J Clin Orthop Trauma 2017; 8(1):34-37.

7. Holick MF, Binkley NC, Bischoff-Ferrari HÁ, Gordon CM, Hanley DA, Heaney RP et al. Clinical Practice Guideline: evaluation, treat- ment, and prevention of vitamin D deficiency: An Endocrine Society Clinical Pactice Guideline. J Clin Endocrinol Metab 2011; 96(7):1911-30.

8. Hood MA, Murtha YM, Rocca GJD, Starnnard JP, Volgas DA, Crist BD. Prevalence of low vitamin D levels in patients with orthope- dic trauma. Am J Orthop 2016; 45(7):E522-E6.

9. Ihle C, Freude T, Bahrs C, Zehendner E, Braunsberger J, Biesalski HK, Lambert C, Stöckle U, Wintermeyer E, Grünwald J, Grünwald L, Ochs G, Flesch I, Nüssler A. Malnutrition - An underestimated factor in the inpatient treatment of traumatology and orthopedic patients: A prospective evaluation of 1055 patients. Injury 2017; 48(3):628-636.

10. King CM, Hamilton GA, Cobb M, Carpenter D, Ford LA. Association between ankle fractures and obesity. J Foot Ankle Surg 2012; 51(5):543-7.

11. Liu S, Zhu Y, Wang L, Chen W, Zhang X, Zhang Y. Incidence and risk factors for foot fractures in China: A retrospective population- based survey. PLoS One 2018; 13(12):e0209740.

12. Maeda SS, Borba VZC, Camargo MBR, Silva DMW, Borges JL, Cunha BF et al. Recommendations of the Brazilian Society of Endocrinology and Metabolism (SBEM) for the diagnosis and treatment of hypovitaminosis D. Arq Bras Endocrinol Metab 2014; 58(5):411-33.

13. Mickle KJ, Steele JR. Obese older adults suffer foot pain and foot- related functional limitation. Gait Posture 2015; 42(4):442-7.

14. Nelson CL, Kamath AF, Elkassabany NM, Guo Z, Liu J. The serum albumin threshold for increased perioperative complications after total hip arthroplasty is 3.0 g/dL. Hip Int. 2019; 29(2):166-171.

15. Nut R, Brandi ML, Checchia G, Di Munno O, Dominguez L, Falaschi P et al. Guidelines for the management of osteoporosis and fragility fractures. Intern Emerg Med 2019; 14(1):85-102.

16. Organização Pan-Americana da Saúde. XXXVI Reunión del Comitê Asesor de Investigaciones en Salud: Encuesta Multicêntrica: Salud Beinestar y Envejecimeiento (SABE) en América Latina e el Caribe. 2001. Washington (DC): OPAS. Informe Preliminar.

17. Ravel R. Laboratório clínico: aplicações clínicas dos dados labora- toriais. 6. ed. 2011. Rio de Janeiro: Guanabara Koogan.

18. Sabharwal S, Root MZ.Impact of obesity on orthopaedics. J Bone Joint Surg Am 2012; 94(11):1045-52.

19. Smith JT, Halim K, Palms DA, Okike K, Bluman EM, Chiodo CP. Prevalence of vitamin D deficiency in patients with foot and ankle injuries. Foot Ankle Int 2014; 35(1):8-13.

20. Stavem K, Naumann MG, Sigurdsen U, Utvåg SE. Association of Body Mass Index With the Pattern of Surgically Treated Ankle Fractures Using Two Different Classification Systems. J Foot Ankle Surg 2017; 56(2):314-318.

21. Tanamas SK, Wluka AE, Berry P, Menz HB, Strauss BJ, Davies- Tuck M, Proietto J, Dixon JB, Jones G, Cicuttini FM. Relationship between obesity and foot pain and its association with fat mass, fat distribution, and muscle mass. Arthritis Care Res (Hoboken) 2012; 64(2):262-8.

22. Torbergsen AC, Watne LO, Frihagen F, Wyller TB, Mowè M. Effects of nutritional intervention upon bone turnover in elderly hip frac- ture patients. Randomized controlled trial. Clin Nutr ESPEN 2019; 29:52-58.

23. Walsh JS, Vilaca T. Obesity, Type 2 Diabetes and Bone in Adults. Calcif Tissue Int 2017; 100(5):528-535.

24. Williams BR, Thomas AJ, Collier RC, Boffeli TJ, Anderson SA. Vitamin D Levels Do Not Predict Risk of Metatarsal Fractures. Foot Ankle Spec 2018; 11(1):37-43.

25. World Health Organization. Obesity: preventing and managing the global epidemic. Geneva: WHO. 2000. Report of a WHO Consultation on obesity.

26. Wortsman J, Matsuoka LY, Chen TC, Lu Z, Holick MF. Decreased bioavailability of vitamin D in obesity. Am J Clin Nutr 2000; 72(3):690-3.