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Original scientific paper

Obesity as a Risc Factor for Diabetic Foot Ulcer

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ABSTRACT: Introduction: Diabetic foot is a term used to describe the foot of a diabetic patient with a potential risk for several pathological consequences, including infection, ulceration and/or destruction of deep tissues associated with neurological abnormalities and different degrees of peripheral vascular disease and/or metabolic complications of diabetes in lower extremities. **Objective:** To determine the relationship between body mass index (BMI) and the characteristics of diabetic foot ulcer, and to offer an answer to the question of whether and in what context obesity can be viewed as a risk factor for diabetic foot ulcer or as a predictor of treatment outcomes. **Methods:** The study was created as a prospective follow-up study, and the total sample contained 33 subjects. Subjects were adult patients of both sex that satisfied determined inclusion criteria. The consent of the competent ethics committee was also obtained. All data were entered into the MS Excel database, and further statistical processing was performed using SPSS 21 program. Statistically significant difference was noted if $P \leq 0.05$. **Results:** The key results of this study are the fact that no statistically significant correlation was found between the diameter and depth of the ulcer at first examination with BMI values ($P = 0.865$ and $P = 0.137$), as well as obesity expressed through BMI with the clinical outcome of diabetic foot ulcer treatment after 2 months ($P = 0.448$). **Conclusion:** There is no proven statistical relationship between diameter and depth of ulcers with BMI, nor the influence of BMI on the clinical outcome of diabetic foot ulcer treatment.

Keywords: diabetic foot ulcer, body mass index, obesity, diabetic polyneuropathy, amputation.

INTRODUCTION

Diabetic foot, according to the World Health Organization *(WHO)*, is the term for the foot of a patient suffering from diabetes, with the potential risk of a number of pathological consequences, including infections, ulceration and/or destruction of deep tissues associated with neurological abnormalities, various degrees of peripheral vascular disease and/or metabolic complications of diabetes in the lower extremities (Novinščak, 2010). The mechanism of diabetic foot formation is multifactorial and complex. A sedentary lifestyle in combination with the accumulation of excess weight triggers the pathophysiological processes of increased body resistance to insulin, which is the basis of the development of type 2 diabetes (Boulton, 2002). Broadly speaking, the two main causes of diabetic foot ulcers are peripheral neuropathy and ischemia. Percentagewise, 60% are neuropathic ulcerations, 20% are ischemic, and 20% are mixed ulcerations (Amstrong, Boulton & Bus, 2017). Male gender, duration of diabetes, smoking, poor foot hygiene, wearing inadequate footwear, poor glycoregulation, presence of eye, cardiovascular and renal complications were also identified as risk factors for the development of diabetic foot. Obesity is also one of the factors that can contribute to increased load on the anatomical structures of the foot (primarily blood vessels and muscles) (Reardon & Simring, 2020). There are projections that by 2030, 6% of the world's population will suffer from diabetes, and that every fourth patient will develop a diabetic foot, while 10 to 30% of these patients will have an amputation (Huljev & Gajić, 2013). Also, there are data that about 25% of people who are treated for diabetes develop diabetic foot, and up to 15% experience amputation. That's why early detection of people with a tendency to develop diabetic foot is a basic condition for adequate treatment, which reduces the risk of amputation. Diabetic foot treatment takes a long time, costs a lot, and the results are often unsuccessful (Metelko & Brkljačić Crkvenčić, 2013). The key to successful treatment of chronic wounds is based on correct diagnosis and modern recognition and discovery of the cause of their occurrence; optimal care conditions; treatment of local and systemic infection; control of local and systemic disorders in the body and prevention of further trauma, as well as correction of hypoxia and stimulation of host tissues to cause an adequate healing process (Situm & Kolić, 2011). Treatment of patients with diabetic feet involves a multidisciplinary approach by a team of experts. There are a number of treatment modalities that include surgical debridement, regular dressings, targeted application of antibiotics according to the results of the antibiogram and treatment of the underlying diseases, as well as other local and supplementary measures. If treatment is not achieved, surgical treatment (amputation) is an option (Driver et al, 2010). In the medical literature, there is very little data on the relationship between diabetic ulcers and body mass index, or data on the relationship between the healing speed of diabetic foot ulcers and body mass index, which was the main reason for creating such a study.

RESEARCH OBJECTIVES

To determine the relationship between body mass index (BMI) and the characteristics of diabetic foot ulcers in patients who are currently treated with hyperbaric oxygenation as an additional therapeutic modality.

To offer an answer to the question of whether and in what context obesity can be considered a risk factor for the occurrence of diabetic foot ulcers or as a predictor of the outcome and length of treatment for diabetic foot ulcers.

MATERIAL, SUBJECTS AND METHODS

The research was designed as a prospective follow-up study. The total sample contained 33 respondents and was collected in the time period from November 1, 2021. until April 1, 2022. The subjects were adult patients of both sexes who were treated or are being treated at the Center for Hyperbaric Medicine and Chronic Wound Treatment, Institute for Physical Medicine and Rehabilitation "Dr. Miroslav Zotović" Banja Luka, for the treatment of diabetic foot ulcers. Inclusion criteria were: indicated treatment for diabetic foot ulcer and patient's signed consent to participate in the study. Exclusion criteria were: no confirmed diagnosis of diabetic foot ulcer; the consent form for participation in the study was not signed, or the patient subsequently withdrew from participation.

The device-type study tools used during the research are a centimeter altimeter, a calibrated scale, a centimeter tape, and a camera. Other materials, drugs, equipment, and medical devices used are part of the standard work process and are in the domain of medical treatment of diabetic foot ulcers. The questionnaire on the first day (diabetic foot ulcer follow-up start) contained questions related to: general data with general anthropometric and demographic data and measurements of the patient and data on the diabetic foot ulcer). This part also contained data on measurements entered by the main researcher. The second part of the questionnaire (at the end of diabetic foot ulcer follow-up – after 2 months) contained data on the outcome of treatment and the appearance of the diabetic foot ulcer (this data was also entered by the researcher). With the consent of the patients, the Informed Consent was signed and a photo gallery of diabetic foot ulcers was created at the start of treatment (1st day) and at the end of treatment (i.e. after 2 months). It is important to emphasize that these were standard procedures and measurements and that no adverse events were expected. The consent of the Management of the Institute for Physical Medicine and Rehabilitation "Dr. Miroslav Zotović" Banja Luka and the consent of the Ethics Committee of the Institute for Physical Medicine and Rehabilitation "Dr. Miroslav Zotović" were obtained. All the collected data were entered into the MS Excel database, and further descriptive processing was carried out with a graphic presentation of the obtained data, as well as the calculation of statistical inference tests using the SPSS 21 program. The assessment of data distribution was performed with the help of the *One-Sample Kolmogorov-Smirnov Test*, and for data which distribution is not normal, non-parametric tests (*Mann Whitney U Test, Kruskal Wallis Test*) were performed, while for data where the distribution is normal, parametric tests were performed (*Studentov T Test, ANOVA Test). Chi Square Test* was used to compare categorical data. As statistically significant values are taken those where P≤0.05.

RESULTS

The study included 33 respondents, average age 62.9 ± 9.9 years, of which 75.8% were men. The mean age of the subjects was 62.9 ± 9.9 years; average height 177.5 ± 7.8 cm; mean BMI 26.8 ± 4.2 kg/m2, with average duration of diabetes 11.1 ± 6.6 years (Tables 1 and 2).

Table 1. shows the frequencies and percentages of the observed variables (gender, age groups and BMI categories and clinical outcomes). Results are presented as frequency and percentage.

DATA	N (%)
♂ gender	25 (75.8%)
♀ gender	8 (24.2%)
40-49 years	5 (15.2%)
50-59 years	8 (24.2%)
60-69 years	11 (33.3%)
≥ 70 years	9 (27.3%)
BMI 18.5-24.9 kg/m^2	8 (24.2%)
BMI 25-29.9 kg/m^2	20 (60.6%)
BMI 30-34.9 kg/m^2	4 (12.2%)
BMI ≥35 kg/m^2	1 (3%)
Complete healing of the ulcer	10 (30.3%)
Ulcer reduction	12 (36.4%)
Inpatient finding of ulcer	7 (21.2%)
Worsening of ulcers	0 (0%)
Limb amputation	4 (12.1%)

Table 1. Frequencies and percentages for parameters: gender, age groups, BMI categories and clinical outcome

Table 2. presents the mean values and standard deviation of the observed parameters/median with IQR, depending on whether the data distribution is normal.

DATA	X ± SD	Mediana (IQR)
Age (years)	62.9 ± 9.9	-
Body mass (kg)	-	81 (76-90)
Body height (cm)	177.5 ± 7.8	-

Body mass index (kg/m²)	26.8 ± 4.2	-
Duration of diabetes (years)	11.1 ± 6.6	-
Ulcer diameter - 1st examination (cm)	-	1.5 (1.0-1.5)
Ulcer depth - 1st examination (cm)	-	0.5 (0.0-0.5)

Table 2. Mean values and standard deviation of observed parameters/median with IQR - depending on the type of distribution.

Table 3. shows statistical testing of the influence of obesity expressed through BMI on ulcer diameter and ulcer depth.

	BMI 18.5-24.9	BMI 25-29.9	BMI 30-34.9	BMI 35-39.9	BMI ≥ 40	P value
DIAMETER OF ULCER Median (IQR)	1.50 (1-1.25)	1.50 (1-2)	1.25 (1-1.50)	-	1.50 (1.50-1.50)	0.865**
ULCER DEPTH Median (IQR)	0.35 (0.05-0.87)	0.35 (0-0.5)	0.5 (0.35-0.87)	-	1 (1-1)	0.137**

* One way ANOVA
** Kruskal Wallis test

Table 3. Statistical testing of the influence of obesity expressed through BMI on ulcer diameter and ulcer depth.

Table 4. shows statistical testing of the influence of age, duration of diabetes and BMI on the clinical outcome of diabetic foot ulcer treatment after 2 months.

	In total	Healing	Reduction	Stationary	Worse	Amputation	P
AGE (X ± Sd)	62.94 ± 9.90	59.2 ± 9.10	63.33 ± 9.33	64 ± 12.14	0	72.25 ± 4.11	0.164*
DURATION OF DIABETES Median (IQR)	10 (6.50-15.00)	7.50 (5.75-12.25)	11 (7.25-19.50)	12 (6-24)	-	9 (4.25-13.75)	0.491**
BMI Median (IQR)	26.60 (24.60-28.35)	26.05 (23.95-28.17)	27 (26.32-30.35)	26.80 (21.50-27.70)	-	27.60 (21.90-31.42)	0.448**

* One way ANOVA
** Kruskal Wallis test

Table 4. Statistical testing of the influence of age, duration of diabetes and BMI on the clinical outcome of diabetic foot ulcer treatment after 2 months

DISCUSSION

Some literature extracts also speak in favor of a higher representation of the male sex, as is the case in this study (75.8%) (Table 1), while hormonal differences and an increased tendency to develop neuropathies and vascular diseases in people are often cited as possible reasons for male gender (Coleman et al, 2013). When it comes to age distribution, in one of the literature excerpts it is found that the largest proportion of subjects with diabetic foot ulcers were aged 58-67 years, 22.6%, while when it comes to BMI, there was 29.6% in the obese category (Bekele et al, 2019). However, we are talking about a study that was carried out in Ethiopia, so these results cannot be completely compared with the results of this research (from Table 1), considering the different climate, race, habits, environmental factors, and others. When it comes to the clinical outcome of treatment after 2 months, in 30.3% of patients the ulcer was completely healed, in 36.4% the ulcer decreased, in 21.2% the ulcer had a stationary finding. No deterioration in diameter was recorded, while 12.1% of subjects had to undergo amputation during the two-month period of treatment and observation (Table 1). Amputation of the lower extremities is most often closely related to a diabetic foot ulcer, which is usually preceded by the development of an infection. In the literature, it is found that in people who have an active diabetic foot ulcer, the final recovery process is 65-75% (Vadivello et al, 2018). Information on the amputation rate of 30.43% was also found, however, the time of follow-up of the patients is not stated, and this information should be taken with reservation in relation to the result of 12.1% of amputated patients in this study (it is possible that some ulcers that are marked as inpatients require amputation) (Bekele et al, 2019). Very important facts when analyzing the percentage of amputee patients is the availability of quality health care for such patients. The high rate of amputations in diabetic foot ulcer patients does not necessarily mean severe forms of the ulcer, but it is sometimes a reflection of poor care and a "laxer" attitude to the decision on surgical treatment that includes amputation.

As a key finding in this research, we single out the fact that no statistically significant correlation was found between ulcer diameter at the first examination and BMI values (observed through defined BMI categories) (P=0.865). In this calculation, we took into account the distribution of the median and IQR values of the ulcer diameter in each defined BMI category. We also did not find a statistically significant association between ulcer depth at the first examination and BMI values (observed through defined BMI categories) (P=0.137). However, a detailed analysis shows that a greater depth of the ulcer corresponds to a higher BMI, so in patients with a BMI ≥ 40, the median ulcer depth was 1 cm, while for BMI 18.5-24.9 the median was 0.35 cm, for BMI 25-29.9 and 30-34.9 the median was 0.5 cm (Table 3). Although the statistical significance of this difference was not proven, these values indicate that patients with a higher BMI have a greater depth of ulcer changes. So, as an answer to the first question of the hypothesis, we can say that the depth of the ulcer increases with the increase in BMI, while the diameter of the ulcer has no statistical association with BMI values.

In this study, we also found no statistically significant association of obesity expressed through BMI with the clinical outcome of diabetic foot ulcer treatment after 2 months (P=0.448), as well as with age and duration of diabetes (Table 4). In this calculation, we took into account the distribution of the median and IQR values for BMI according to the defined possible categories of clinical outcome (complete healing, reduction of ulcer, stationary finding, worsening of ulcer, and amputation of external limb). So, as an answer to the second question from the hypothesis, it can be said that we did not find a correlation between BMI and the outcome of diabetic foot ulcer treatment. One possible reason is the small sample size.

In general, the prevalence of overweight has increased dramatically in the USA over the past 50 years, so we find that in 2010, 69.2% of the population had a BMI greater than 25. Furthermore, it is believed that in the next 20 years in the USA, obesity will continue to grow, and that in 2030 there will be more than 65 million obese people in this territory (Wang et al, 2011; Nongmaithem et al, 2016). Thinking in this way, great pressure is expected on the healthcare system when it comes to chronic wounds such as diabetic foot ulcers.

Some of the limitations of this research, in addition to the fact that the sample is quite small, is that the localization of diabetic foot ulcers was not recorded, while the findings of other studies indicate a dominant plantar localization of these changes with a frequency of 58.3% (Bekele et al, 2019). Also, the limitation of this study was the measurement of the depth of the ulcer, which cannot be declared as a completely reliable measurement due to the different appearance of each observed diabetic foot ulcer, but also that we did not monitor the healing process according to the *cm²/week* formula.

CONCLUSION

This research did not prove a connection between the diameter of the ulcer and BMI, while when we talk about the depth of the ulcer, we see a positive dynamic in relation to BMI values, although without statistical significance. Also, there is a certain positive dynamic of BMI with clinical outcomes of diabetic foot ulcer treatment, but without statistical significance. Diabetic foot ulcer is ultimately a complex problem, where it is very difficult to say to what extent obesity is the cause, and to what extent it is the consequence of the disease.

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