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Comparison of Muscle Mass, Total Body Water and Total Body Protein in Type II Diabetics with Healthy Matched Adults by Bioelectrical Impedance Analysis

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ABSTRACT

Background: Bioelectrical impedance analysis (BIA) is a new and rapid technique to validate body composition. Several studies have used this technique to evaluate body compositions, such as muscle mass, in diabetic patients, but the results are very different. This may due the differences between diabetic patients and control group. Therefore, this study aimed to compare the muscle mass of diabetic patients with healthy matched adults using the BIA method. **Methods:** This descriptive cross-sectional study was conducted on 928 diabetic patients and 928 healthy individuals selected based on gender, age, height, weight, and closeness to demographic conditions. Body composition was measured by the BIA technique. Total body water, muscle mass in the trunk, legs, hands, and total body protein were measured by this method. The data were analyzed using t-test, paired t-test, and one-way ANOVA. **Results**: Diabetic women aged 50-60 years showed that their body weight, total protein, total muscle, right-hand muscle mass, left-hand muscle mass, right foot muscle mass, left foot muscle mass, and trunk muscle mass were higher than healthy matched women, and the differences were significant. **Conclusion:** Diabetic women aged 50-60 years showed the most significant difference compared to other age groups. It seems that diabetes along with the changes in humeral status in this age group due to menopause affected their body weight, total muscle mass, hand and leg muscles, and trunk muscles mass, and total body protein compared to healthy matched women. However, diabetic men showed no significant difference in the studied variables compared to healthy male subjects.

Keywords: *Body composition; Bioelectrical impedance analysis; Diabetes, Muscle condition*

Introduction

Diabetes is a metabolic disorder, which the number of people affected by this disease has increased over the past years. It is estimated that by 2025, the number of affected people will double (Baltadjiev and Baltadjiev, 2011). The authors aimed to evaluate the role of body composition on detection of diabetes (Baltadjiev and Baltadjiev, 2011). Muscle mass makes up 30 to 40 percent of

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the body weight playing a key role in the body movements and metabolism (Kuriyan *et al.*, 2008).

Different methods have been developed for body composition evaluation. Bioelectrical impedance analysis (BIA) is a new and rapid technique, with the ability to repeat and validate body composition. By this technique, the amount of water, protein, muscle mass can be measured in individual organs and in general (Jahanlou and Kouzekanani, 2015, Spotti *et al.*, 1993). Several studies have used this technique to evaluate muscle mass changes in diabetic patients (Baltadjiev and Baltadjiev, 2011). For instance, it was reported that muscle mass in healthy individuals was more than diabetic patients (Baltadjiev and Baltadjiev, 2011); whereas, Halvatsiotis *el al.* could not find any significant difference (Halvatsiotis *et al.*, 2002). Andersen and Sayer in their studies reported the reduction in muscle strength in the lower body of the diabetic patients (Andersen *et al.*, 2004, Sayer *et al.*, 2005). On the other hand, Shakibi *et al.* observed soft tissue disorders in the upper limbs of diabetic patients (Shakibi *et al.*, 2003). These differences in results could be due the difference in measurement instruments, race, the small number of samples, and lack of matching between patients and the group. This study aimed to compare the muscle condition of diabetic patients with healthy individuals by the BIA method.

Materials and Methods

Study design and participants: This descriptive cross-sectional study was started from 2009 and was jointly running between Texas M & A University and Hormozgan University of Medical Sciences. All individuals referred to Bandar Abbas Nutrition and Health Consultation Center were selected by census. Informed consent was obtained from all patients before entering the project. The exclusion criteria included people under the age of 30, people with type 1 diabetes, type 2 diabetic patients who use insulin, people with previous history of hospitalization in the last 3 months, pregnant women, people with a history of heart and kidney disease, people with pacemakers, people with the history of losing weight in the past 3 months, and those who were reluctant to participate in the project.

Overall, form 23395 patients in these years, 11711 patients entered to this research. Most people excluded from the study were people under the age of 30. A total of 994 participants with type 2 diabetes (T2DM) and over the age of 30 were selected. For each patient, one person was selected based on gender, age, height, weight, and closeness to demographic conditions. An exact match was not found for 66 diabetic patients. Overall, 928 people with T2DM and 928 people as a control group were selected by the matching method and entered in the study.

Measurements: Body composition was measured by the BIA method by using the Plusavis 303 device (Jahanlou and Kouzekanani, 2015, Spotti *et al.*, 1993).. With a frequency of 50 to 250 MHz, this device can measure body composition, including total body water, total muscle and muscle mass in trunk, legs, hands, and total body protein. The accuracy of this method was confirmed in previous studies in comparison with complex techniques, such as X-ray.

The necessary information was provided to the participants using four posters mounted in four points of the center and free brochures. The questions of the participants about how the device works and other information were provided by the technician. The study variables included total body water, total body protein, and muscle mass in the trunk, hands, and feet (left and right split).

Ethical considerations: This study approved jointly between Texas M & A University and Hormozgan University of Medical Sciences (code: 2009.6.May,6-HEC-88-2-16). Informed consent was obtained from all patients before entering the project.

Data analysis: Data analysis was performed using SPSS software version 22. Moreover, t-test analysis was used for mean comparison, and pair t-test was used to compare the type II diabetic subjects with the same control individuals. The studied variables among different age groups were analyzed by one-way ANOVA. Ten-year age group and gender groups were used for statistical comparison.

Results

In this study, 1856 individuals in diabetic and control groups (each group 928 individuals; 621

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women, 307 men) were evaluated. In terms of the factors studied in the patients and the control group, mean comparison of the studied variables between the two groups did not show any significant difference between the two groups by Student *t-test*. The same comparison was made by gender, and no significant difference was observed between the investigated factors.

A statistical comparison between the person with diabetes and a matched control group showed that all the studied variables in the diabetic group were more than the control group, which were significant ($P < 0.01$). For more detailed information, the variables were examined based on gender. The difference in the studied variables between diabetic men and healthy matched men was not significant. But in diabetic women, all of the studied variables were more than healthy women which were significant ($P < 0.01$) (**Table 1**).

To determine the age group with more changes, the comparison was performed based on the age distribution of diabetic women and healthy matched women. The results showed that the variables were different in women in the age group of 50-60 years. In this age group, body weight, total protein, total muscle, right-hand muscle mass, left-hand muscle mass, right foot muscle mass, left foot muscle mass, and trunk muscle mass were higher than healthy matched women, and these differences were significant ($P < 0.01$) (**Table 2**).

The statistical comparison based on one-way ANOVA showed that the body weight and total muscle mass in the 50-60 years diabetic and healthy women groups were significantly less than the 30-40 years women. Body protein content in healthy women in the 40-50 and 50-60 age groups was significantly lower than healthy women in the 30-40 age group. In diabetic women aged 50-60 years, the total body protein in diabetic women was considerably lower than diabetic women in the age group of 30-40 years. Trunk muscle mass in both groups of women in the age group of 50-60 years was significantly lower than the age group of 30-40 year.

There was no significant difference in the right-hand muscle mass and left-hand muscle mass in the diabetic and matched control group and in different age groups. However, the level of trunk muscle mass in diabetic and control women in the 50-60 age group were significantly lower than women in the 30-40 age group ($P < 0.01$).

To evaluate the symmetry of hand and foot muscle mass, the data were analyzed by paired t-test method. Overall, there was no significant difference between the amount of right and left muscles in the right and left-hand and foot in healthy women. The same results were repeated about healthy women based on the age-related analysis. However, in diabetic women, the amount of muscle on the right side was significantly more than the left side of the body. For a better result, the survey was conducted based on age classification. The results showed that in diabetic women in the age range of 50-60 years, the left foot muscle mass was significantly less than the right side and, but no significant difference was observed among other age groups ($P < 0.01$).

Analysis of the data in the men did not show any significant difference in terms of the total studied variables among the patients with their healthy matched subjects. Based on the factors studied in diabetic and healthy men, in healthy men, mean body water, body protein, total body muscle mass, right muscle mass, left muscle mass, right foot muscle mass, left foot muscle mass, and trunk muscle mass in the age group of 50-60 and 60-70 years were significantly lower than the 30-40 and 40-50 years age groups ($P < 0.01$).

In diabetic men, the mean of body water, body protein, total muscle mass, right-hand muscle mass, left-hand muscle mass, right foot muscle mass, and trunk muscle mass in the age group of 50-60 and 60-70 years were significantly lower than the 30-40 and 40-50 years age groups. Left foot muscle mass in the age group of 50-60 years was less than the 30-40 years and 50-40 years age groups ($P < 0.05$).

In healthy and diabetic men, the amount of muscle mass in the right-hand and foot was significantly higher than the left muscle mass ($P < 0.01$). The healthy individuals in the 30-40 age group, the left-hand and feet muscles mass was significantly lower than right side muscles mass. In diabetic patients with the same age range, the

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amount of left-hand muscle mass was significantly lower than right-hand muscles mass. In diabetic and healthy men in the 40-50 years age group, the amount of left-hand and foot muscle mass was significantly lower than the right side of the body. In men in the 60-70 years age group, the left-hand muscles mass was substantially lower than right side muscles mass. However, there was no significant difference in the left and right leg muscles mass of the patients. In the control group with the age range of 60-70 years, the muscles of the left-hand and foot were significantly lower than the right-hand and foot ($P < 0.01$).

Table 1. Comparison of mean (±SE) of determined factors between diabetic patients and healthy individuals based on gender.

Variables	Total N=928 Control	Total N=928 Diabetic	P-value[a]	Control N=307 Men	Diabetic N=307 Men	P-value	Control N=621 Women	Diabetic N=621 Women	P-value
Body water (kg)	37.3±7.4	37.7±7.4	0.01	44.2±6.8	44.6± 6.8	0.10	33.9±4.8	34.3± 4.9	0.01
Total protein (kg)	10.0± 2.1	10.2± 2.1	0.01	12.4±1.8	12.5± 1.8	0.10	8.9±1.1	9.07± 1.1	0.01
Total soft tissue (kg)	47.4± 9.5	47.9± 9.5	0.01	56.7±8.6	57.1± 8.7	0.10	42.9±6.0	43.4± 6.0	0.01
Right arm muscle (kg)	3.3± 0.7	3.3± 0.7	0.01	4.0± 0.6	4.0± 0.6	0.20	2.9±0.4	3.0± 0.5	0.01
Left arm muscle (kg)	3.3± 0.6	3.3± 0.7	0.01	4.0± 0.6	4.0± 0.6	0.10	2.9±0.4	3.0± 0.4	0.01
Right leg muscle (kg)	8.7± 1.8	8.8± 1.9	0.01	10.4±1.8	10.5±1.8	0.10	7.9±1.2	8.0±1.3	0.01
Left leg muscle (kg)	8.7± 1.8	8.8± 1.9	0.03	10.3±1.8	10.4±1.7	0.06	7.9±1.2	7.9±1.3	0.01
Abdominal muscle (kg)	23.3± 4.4	23.5± 4.5	0.01	27.8± 3.8	28.0± 3.9	0.10	21.1±2.7	21.3± 2.8	0.01

[a]: Student *t-test*.

Table 2. Comparison of mean (±SE) of determined factors between diabetic women and healthy women based on age groups.

Variables	Control N=122 30-40(y)	Diabetic N=122 30-40(y)	P-value[a]	Control N=206 40-50(y)	Diabetic N=206 40-50(y)	P-valu	Control N=231 50-60(y)	Diabetic N=231 50-60(y)	P-value	Control N=56 60-70(y)	Diabetic N=56 60-70(y)	P-value
Body water (kg)	35.4±4.5	35.5±4.6	0.30	34.3±5	34.6±5.0	0.03	33.2±4.6	33.7±4.7	0.01	33.2±5.1	33.5±5.2	0.20
Total protein (kg)	9.3±1.0	9.3±1.0	0.40	9.0±1.2	9.1±1.2	0.03	8.7±1.0	8.9±1.1	0.01	8.7±1.2	8.8±1.3	0.20
Total soft tissue(kg)	44.7±5.5	44.9±5.6	0.30	43.3±6.2	43.8±6.3	0.03	41.9±5.7	42.6±5.8	0.01	41.9±6.3	42.3±6.4	0.20
Right arm muscle (kg)	3.0±0.3	3.1±0.4	0.10	3.0±0.4	3.0±0.5	0.10	2.9±0.4	3.0±0.4	0.01	3.0±0.5	3.0±0.5	0.50
Left arm Muscle (kg)	3.0±0.3	3.0±0.4	0.40	3.0±0.4	3.0±0.4	0.03	2.9±0.4	3.0±0.4	0.01	2.9±0.5	3.0±0.5	0.20
Right leg Muscle (kg)	8.2±1.1	8.3±1.2	0.40	8.0±1.3	8.1±1.3	0.04	7.7±1.2	7.8±1.2	0.01	7.6±1.3	7.8±1.3	0.10
Left leg muscle (kg)	8.2±1.1	8.3±1.2	0.70	7.9±1.3	8.0±1.3	0.06	7.7±1.2	7.8±1.3	0.01	7.6±1.3	7.8±1.4	0.10
Abdominal muscle (kg)	22.0±2.5	22.1±2.5	0.30	21.3±2.8	21.4±2.8	0.08	20.0±2.5	20.0±2.7	0.01	20.5±2.9	20.6±2.8	0.50

[a]: Student *t-test*.

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Table 3. Comparison of mean (±SE) of determined factors between diabetic men and healthy men based on age groups.

Variables	Control N=82 30-40(y)	Diabetic N=82 30-40(y)	P-value[a]	Control N=108 40-50(y)	Diabetic N=108 40-50(y)	P-value	Control N=85 50-60(y)	Diabetic N=85 50-60(y)	P-value	Control N=28 60-70(y)	Diabetic N=28 60-70(y)	P-value
Body water (kg)	46.5±7.1	46.9±7.4	0.2	45.4±6.7	45.7±6.6	0.4	42.1±6.0	42.3±5.7	0.4	40.0±4.8	41.0±5.3	0.4
Total protein (kg)	13.0±1.8	13.1±1.9	0.2	12.7±1.8	12.8±1.8	0.5	11.8±1.6	11.9±1.5	0.3	11.3±1.3	11.5±1.6	0.3
Total soft tissue (kg)	59.5±9.0	60.0±9.4	0.2	58.2±8.6	58.5±8.4	0.4	53.9±7.7	54.3±7.3	0.4	51.8±6.1	52.6±6.9	0.4
Right arm muscle (kg)	4.1±0.6	4.3±0.7	0.03	4.1±0.6	4.1±0.6	0.9	3.8±0.5	3.8±0.6	0.9	3.7±0.4	3.7±0.5	0.3
Left arm muscle (kg)	4.1±0.6	4.2±0.6	0.03	4.1±0.5	4.1±0.5	0.8	3.8±0.5	3.8±0.5	0.8	3.7±0.4	3.7±0.5	0.7
Right leg muscle (kg)	10.9±1.9	11.0±1.9	0.3	10.7±1.8	10.8±1.8	0.5	9.8±1.6	9.9±1.5	0.3	9.4±1.3	9.6±1.5	0.5
Left leg muscle (kg)	11.2±1.1	11.3±1.2	0.7	10.9±1.3	10.8±1.3	0.06	9.7±1.2	9.8±1.3	0.1	9.6±1.3	9.8±1.4	0.1
Abdominal muscle (kg)	29.3±4	29.5±4.1	0.3	28.5±3.8	28.6±3.7	0.3	26.5±3.3	26.6±3.2	0.5	25.4±2.8	25.8±3.0	0.4

[a]: Student *t-test*.

Discussion

In this study, diabetic men showed no significant difference with healthy male participants in the studied variables; however, diabetic women aged 50-60 years showed the highest change compared to other age groups. It seems that diabetes along with the changes in humoral status in this age due to menopause affected body weight, total muscle mass, hand and leg muscles, and trunk muscles mass, and total body protein of this age group compared to the healthy matched women. In the study conducted in Japan on 10335 healthy individuals by BIA method, it was observed that in both gender, muscle mass decreased after the age of 50, which is consistent with the results obtained in this review (Yonei *et al.*, 2008).

In the other study, Owolabi compared 100 African patients with T2DM with healthy individuals and showed that fat content in diabetic patients was significantly higher than healthy people. However, there was no difference in muscle mass between the two groups (Owolabi *et al.*, 2016). The reason for the differences between these findings and the present study findings could be due to differences in the number of samples and differences in race.

In this study, the left leg muscle mass of diabetic women was lower than the right leg muscle mass, which was not seen in other age groups of women, but there were many differences in hand and leg muscle mass and muscle mass in healthy men.

Considering the lack of difference in terms of the studied variables in both groups, it can be suggested that the difference between the right and left muscles mass does not correlate with the condition of the disease or the health of people and it may be related to issues like shoes, sports, and other reasons.

The study conducted by Tajiri on 198 diabetic patients and 198 healthy individuals by the BIA method indicated that the percentage of whole body skeletal muscle in the diabetic group was significantly lower than the control group. This is more common in people with a long-term history of diabetes and people with low mobility (Tajiri *et al.*, 2010). In this study, women with diabetes aged 50-60 years had more muscle mass than their matched women, and in other age groups of men and women, significant differences were not

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observed. The difference between the present study and the results obtained by Tajiri is due to the difference in the number of specimens (928 versus 198), age distribution, genetic differences, lifestyle, and coherence of the patient and healthy subjects in this study. However, given that differences are only observed in diabetic women aged 50-60, compared to healthy women, it could be due to hormonal changes during menopause, reducing the amount of estrogen that can be a risk factor for metabolic diseases (Balas-Nakash *et al.*, 2010).

Yu *et al.* reported that sarcopenia or loss of muscle tissue is a natural phenomenon in the aging process (Yu *et al.*, 2016). In this study, the muscle mass of the body in each age group is less than the age group before itself, which is common in diabetic patients and healthy individuals and in both genders, which is consistent with Solomon's study. It is important to note that in the current study, in diabetic women ageed50-60, the body protein, total muscle mass, muscle mass of hands and feet, trunk muscle mass, and total body water were higher than women in the control group. It should be noted that the high levels of protein and water in a group of diabetic women need further examination of the effects of menopause and changes in hormone levels on the studied variables in healthy and diabetic patients.

Malo *et al.* reported on older people, especially women, showed a high level of disability due to a reduction in muscle and bone mass (Melo *et al.*, 2015), which is consistent with the results obtained in the present study for diabetic patients and control groups and both genders. However, due to the difference between diabetic women aged 50-60 with healthy matched women, in terms of muscle mass in the whole body and organ differentiation, it can be assumed that menopause and hormonal changes during this period affect the body composition of diabetic and healthy women.

Conclusion

The most significant difference was observed only in the group of women aged 50-60 years; it seems that the combined effects of diabetes and menopause in this period had the most significant impact. The comparison of right and left limbs among men and women showed that men had the greatest difficulty in muscle differentiation between the right and left sides of their body, considering that there was no difference in other examined cases, it seems that this muscle was not related to diabetes. In the light of the results of this study, it is suggested that a BIA-based study of body composition based on hormonal changes should be conducted in diabetic and healthy matched women aged 40-60 years. It is recommended that future researchers measure the quality of arms and legs in diabetic subjects in their studies.

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Conflict of interest

The authors declare that there is no conflict of interest.

Authors' contributions

Jahanlou P and Jahanlou ASH conceived and designed the study. Jahanlou ASH performed the statistical analysis, data interpretation. Jahanlou P drafted the manuscript. Jahanlou P and Jahanlou ASH critically reviewed the manuscript. All authors read and approved the final version of the manuscript.

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