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# BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) OF BODY SEGMENT COMPOSITION AS AN OBESITY ASSESSMENT TOOL AMONG JORDANIANS

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## ABSTRACT

Bioelectrical impedance analysis (BIA) is a body composition assessing technique for estimating body components; fat, and muscle mass, and body water (BW) by measuring the electrical resistance in ohm (Ω) of those components with response to the flow of a small electrical current through the body. Bioelectrical impedance analysis was used to investigate the relationships between segmental body composition, obesity and body mass index (BMI). The analysis in this study involved the use of InBody 370S equipment to conduct the body composition study of 48 adult participants (30 females and 18 males) at the Applied Science Private University (ASU) School of Pharmacy, Department of Clinical Nutrition and Dietetics, between October, 2019 and January, 2020, Jordan. Anthropometric parameters such as weight, height, body mass index (BMI), and waist-to-hip (W/H) ratio for each individual were measured. The values indicated that BMI of 26.5 for males and 25.42 for females and body composition such as body fat mass (BFM), protein, and visceral fat level (VFL) of females of BMI > 30 was 39.82 compared to 32.60 for males of the same category. The VFL for female individuals was higher than males (13.0 and 17.5) of the same BMI category. The results of BIA analysis, lean body mass, and body muscle mass were found to be significantly ($p$ <0.05 ) correlated in obese adult females but not in obese males, where the body fat mass (BFM) of females with BMI > 30 was 39.82±4.35 compared to 32.6±3.67 for males of the same group. Additionally, the BFM (−3.86**), segmental muscle mass (SMM) was 0.784**, and total body water (TBW) of −0.658** were all indirectly correlated at ($p$ <0.01) with the BIA impedance evaluated as Z(Ω) at 250 kHz. However, the lean mass of the left arm ( −0.662**) and left leg muscle (− 0.514**) were found to be significantly correlated ($p$ < 0.01) and lower in identified obese females compared to non-obese individuals. The findings demonstrate the strong correlation between lean and fat segmental analysis values, and the level of obesity and segmental analysis for male and female individuals can be taken into consideration in obesity and disease prevention.

**Key words:** BIA, obesity, segmental analysis, body composition, BMI, WHR, VFL

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## INTRODUCTION

The use of body composition in assessing the nutritional status is largely recognized as an important tool in assessing changes in obesity occurrence among adults and children [1]. The increase in fat buildup in various parts of the body can result in the development of a number of health problems, including Type II diabetes, cardiovascular diseases, and liver and kidney dysfunctions [2, 3, 4]. Body composition analysis can be used to assess the degree and kind of intervention required by evaluating the prevalence of obesity in targeted groups [3, 5].

Body composition analysis using the BIA technique is considered one of the accepted tools used in body composition evaluation as compared to the device commercially named BOD POD (Life Measurement Instrument, Concord, CA, USA) and dual-energy X-ray absorptiometry (DEXA) [6, 7]. The BOD POD instrument uses the same technology of Air Displacement Plethysmography (ADP) in measuring thoracic and body gas volume. The plethysmography, also known as BOD POD body composition analysis instrument uses air rather than water displacement through hydrostatic measurement to divide the body into two compartments, and calculates the ratio of fat mass (FM) to fat-free-mass (FFM) [8, 9, 10]. The approach considers the body to be one cylinder and avoids the constraints resulting from using a single-frequency body composition analysis technique. BIA widely used by nutritionists to measure body composition (BC) because it is fast, simple, convenient and can be used of individuals of all ages. The electrical properties of different body tissues in estimating body composition, such as the amount of lean tissues, fat, and bone [11, 12, 13]. Lean tissues, like muscles, have high water and electrolyte content, making them good conductors of electricity with low resistance. On the other hand, fat and bone have lower water and electrolyte content resulting in greater electrical resistance due to their poor conductivity [14, 15, 16]. Through measuring resistance, reactance, impedance, and phase angle with a low- amplitude and high-frequency current, body composition can be estimated accurately. An important innovation called segmental bioelectrical impedance has been developed based on these principles, demonstrating that by assessing the resistance of the arm, leg, and trunk, it is possible to directly calculate total fat-free mass. Currently, the new instrument measures the fat or muscle distributions along the body parts using multi-frequency signals that BIA divides the body into 5 parts. This defines that the body is not uniform and uses the following components: trunk (TR), right arm (RA), left arm (LA), right leg (RL), and left leg (LL)) to provide a more accurate assessment of body composition [9, 14, 15]. Therefore, the study aimed to evaluate obesity using multi-frequency bioimpedance in the evaluation of the components of body segments.

## MATERIALS AND METHODS

### Participants and Body Composition Measurements

Forty- Eight healthy adults (18 men, 30 women aged ≥18 yrs.; BMI> 18.5) selected by means of convenience sampling from employee and students of Applied Sciences Private University (ASU) attended an open day activity at ASU and volunteered to participate in the cross-sectional study conducted at Faculty of Pharmacy at ASU in Amman /Jordan between October 2019 and January, 2020. Only healthy adults were eligible to enroll in the study, participants had to be between the ages of 18 and 65 years of age and their obesity calculated and classified according to body mass index (BMI ≥ 30 kg/m$^2$). Exclusion criteria included participants < 18 and > 65 years old and BMI<18.5 and those who had surgical metal or electrical implantation. Height was measured by Inbody ultrasound portable stadiometer (InBody Co., Seoul, Republic of Korea) and waist and hip circumference were measured manually by measuring tape (UK, Wales) prior to body composition analysis that performed by using a 5-segmental bioelectrical InBody 370S (InBody Co., Seoul, Republic of Korea) that uses technology based on simultaneous multi-frequency (5, 50, 258 kHz) bioelectrical impedance analysis (SMF-BIA). The participants were instructed to comply with the protocol of measurements regarding exercising and types of clothes prior to Inbody measurements that performed at ASU campus, Department of Clinical Nutrition and Dietetics within a 30-min. The body composition measured by InBody 370s include skeletal muscle mass (SMM, kg), Body fat mass (BFM, kg), percent body fat (PBF, %), fat free mass (FFM, Kg), soft lean mass (SLM, kg), visceral fat level (VFL, 1 to 9) which determine fat content in each body segments, and minerals (Figure 1).

The correlation between the body composition parameters of all participants were made to determine the agreement between each body for the estimation of percent body fat (PBF %) and fat free mass (FFM in kg), segmental lean analysis, and segmental fat analysis defined as a percent of measured to normal values and interpreted as normal, or under or over compared to the ideal reference values. Before starting activities of taking body composition measurement, enrolled participants were informed about the study procedure and participants gave their verbal and written informed consent.

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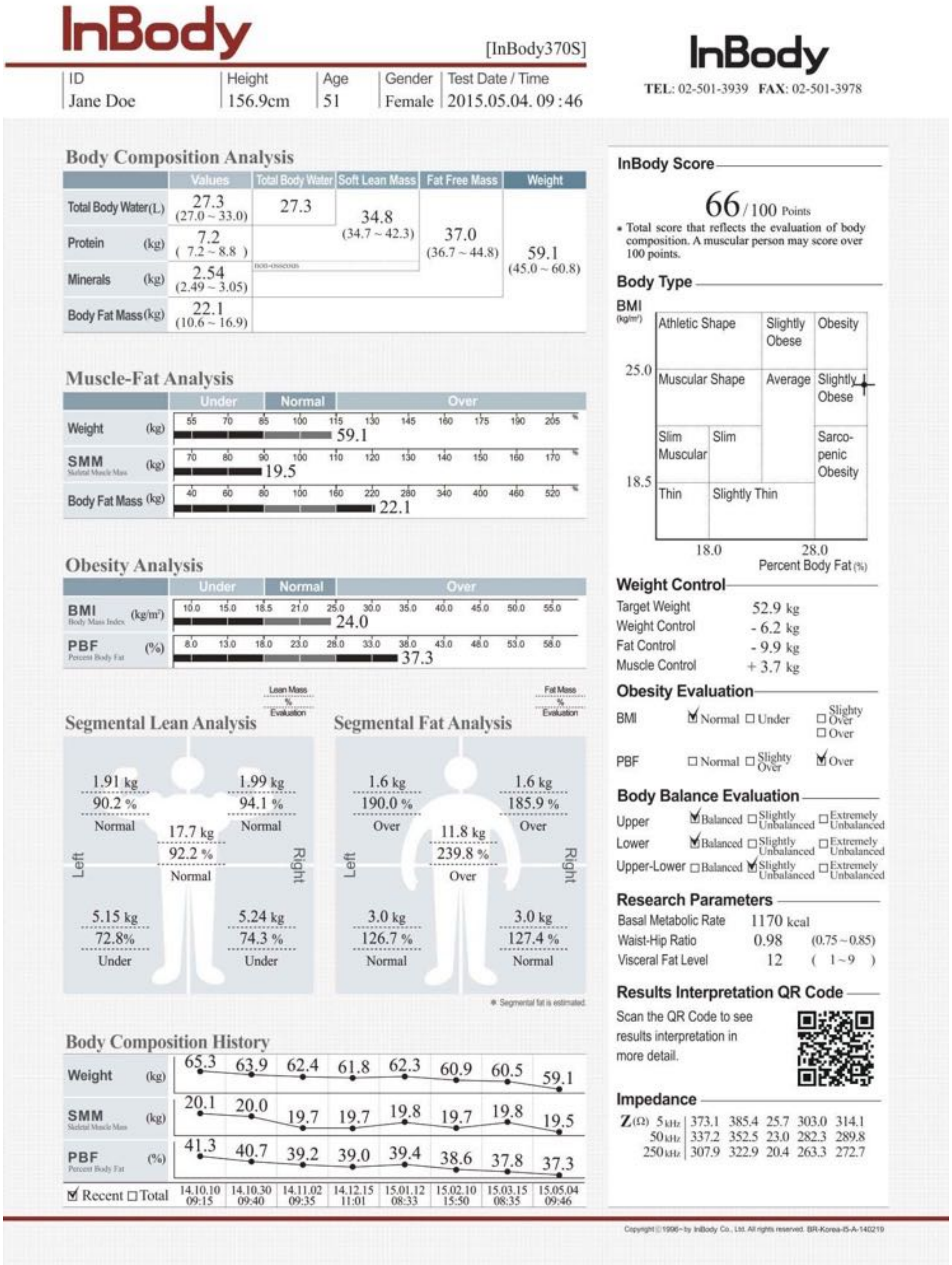


**Figure 1: The Results Sheet obtained from the InBody 370S instrument**

## Statistical Analysis

The correlations between the segmental measurements and BMI were statistically analyzed using the Statistical Package for the Social Sciences ver.22 package (IBM Corp, Armonk, NY, USA). The association between lean and fat segmental measurements, BFP, FFM, BMI, and TBW were determined using linear regression. The significance level was evaluated at $p < 0.05$.

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## RESULTS AND DISCUSSION

The weight, height, body mass index (BMI), and waist-to-hip (W/H) ratio (anthropometric parameters) of the recruited individual results are presented in Table 1. It is clear that the average BMI value of the selected participants (males, females) were almost similar, 26.5±1.38 and 25.42±0.93 for males and females, respectively. Although there is a small difference in BMI of males compared to females, according to the BMI reference classification (25< BMI ≤ 30), both male and female participants are considered as overweight. The body composition of the measurements of body FM, protein, and visceral fat level (VFL) are shown in Table 2. The female BFM of those having BMI > 30 was 39.82 ± 4.35 compared to 32.60 ± 3.67 for males of the same group of BMI > 30. The VFL for the female individuals was higher than that of males of the same group at 13.00 ± 0.68 and 17.50±1.66, respectively. There was a significant difference between male and female body composition for all measured variables. The visceral fat increases with the increase in BMI, body FM, and soft lean mass (Table 2) and is directly correlated with BMI (Table 2). The use of BMI as an alternative for body composition measurements appears less accurate than more recently developed methods (Inbody segmental analysis, DEXA) as it is confounded by several limitations [17, 18]. The BMI takes into consideration only the weight and height of an individual and this is not an exceptionally good marker for either obesity or health status, and it is not necessarily true that persons having same BMI have the same percent fat. Therefore, other measurements should be considered in evaluating nutritional and health status [17, 19]. The Inbody 370s instrument used for evaluation of health status with reference to body composition such as BF %, FFM, SMM, and their correlations with the segmental impedances showed there was a significant correlation of health status with body compositions. The results obtained in this study for BF%, FFM, SMM are in agreement with those found by Shafer *et al.* [19], who concluded that predictions from the evaluation of body composition were less accurate compared to results from the impedance method for healthy adults [4, 19, 20].

The BIA Impedance (Z **Ω**) at 250 kHz chosen because it is a proxy marker for body composition and calculated parameter [21] and was significantly correlated with BFM, SMM, and TBW as shown in Table 3. Pearson correlation between the segmental analysis at 250 kHz and Segmental Fat Analysis showed a significant correlation (Table 4). The *Pearson* correlations between Right arm fat (RAF), Left arm fat (LAF), Trunk fat (TRF), Right leg fat (RLF), and Left leg fat (LLF) and related impedances of Right arm (RA), left arm (LA), Trunk (TR), Right leg (RL) and Left leg(LL) were indirectly associated as the impedance decreased the fat level in body segments increased.

The association between the BMI level and body composition parameters are presented in Table 5. The results show significant correlations between BMI and BFM, VFL, WC, and W/H (p=0.01) and the size effect are also high as indicated by the *Eta* value. On the contrary, no significant correlations were found between BMI and TBW, SLM and SMM (p> 0.05).

In the present study, segmental impedance was used to evaluate health status based on body composition analysis in accordance with BF% and muscle mass, visceral fat, and waist–to–hip ratio. The results obtained were in agreement with those reported by Ling *et al.* [22] who used direct segmental multi-frequency bioelectrical impedance analysis (DS-BIA) for body composition measurements. The results found were very close to the results usually obtained by the DEXA and without the limitation of exposure to X-ray providing the opportunity to take several repeated measurements without a risk of radiation. Additionally, results were more accurate compared to values obtained by BIA using single frequency or those predicted using equations that underestimate body parameter values such as BF %, SMM, and VFL. The SMF-BIA is an effective tool for body composition and segmental lean mass analysis [9, 23, 24]. The results obtained in the current study were in agreement with those found by Esco *et al.* [9] regarding the importance of SMF-BIA and DEXA, where it was shown that the total and body lean soft tissue measurements yielded equivalent results. The soft lean mass (SLM) and the skeletal muscle mass (SMM) values measured by the Inbody were not significantly different when compared with BMI and gender at a *p* value of > 0.05. The segmental body composition analysis is considered a comparable technique for measuring the segmental lean mass using the SMF-BIA the most versatile and rapid in providing precise measurement values [9]. The associations between impedances of the trunk were in accord with previous studies that showed the size effect of the trunk to whole body impedance of about 10% which was mostly equivalent to 50% of the whole-body mass [6,24]. Visceral fat is also a useful marker in diabetes type 2, cancer, and health diseases with conformance of the MF_BIA 370s results and the correlations between VFL and BFP [25]. The waist to hip ratio and visceral fat level were highly correlated with BMI that can be used as a reference marker to obesity (BMI ≥30) as shown in Table (5) and this results were in agreement with Gadekar *et al.* [26] who found strong association between VF and WHR.

## CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

In conclusion, describing body composition using segmental bioimpedance analysis using SMF-BIA is an excellent convenient, inexpensive, and noninvasive tool for evaluating body composition in Obese and healthy individuals. It can be used to locate the distribution of body fat within the main body segments and to obtain valuable information about visceral and total body fat levels in comparison to single frequency analysis technique with significant correlations among measured parameters.

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None.

**Conflicts of interest**
None.

**Author contributions**
Ahmad Sundookah and Amin Olaimat: participated in data collection and revised the article.
Yazeed abu-Hanak: participated in data collection.
Mahmoud Abu- Samak: data interpretation.
Mohammad Majali, Hani Dmoor and Ibrahim Dabbour : Data collection
Saqer Herzallah, participated in data collection, writing the article and data analysis.
Rick Holley, Reviewing and editing the article.

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**Table 1**: **Subject anthropometric parameters (n=48)**[1]

| Parameter | (Mean ± SEM) | | Min. | | Max. | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Age (year) | 30.3 ± 4.35 | 26.36 ± 2.29 | 18 | 18 | 52 | 65 |
| Height (cm) | 177.6±2.22 | 161.9±1.32 | 169 | 147 | 193 | 184 |
| Body weight (kg) | 84.2±5.74 | 66.35±2.22 | 57.1 | 44.6 | 116.1 | 95.9 |
| Body mass Index (BMI) | 26.5±1.38 | 25.42±0.93 | 19.3 | 18.6 | 33.9 | 44.4 |
| Waist-to-Hip ratio (W/H) | 0.94±0.02 | 0.91±0.01 | 0.81 | 0.74 | 1.04 | 1.00 |

[1]Female (n==30) and Male (n=18)

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**Table 2: Body composition parameters measured by BIA according to BMI**

| Body Composition[2] | BMI[1] Normal (18.5-24.9) (Mean ± SEM) | | Overweight (25.0 -29.9) (Mean ± SEM) | | Obese >30 (Mean ± SEM) | |
|---|---|---|---|---|---|---|
| | Male[3] (44%) | Female[4] (30%) | Male (39%) | Female (50%) | Male (17%) | Female (20%) |
| Skeletal Muscle Mass (SMM, kg) | 31.12±1.92 | 20.98±0.84 | 46.76±9.07 | 23.58±0.98 | 48.2±4.91 | 24.05±1.16 |
| Body Fat Mass (BFM, kg) | 13.10±2.46 | 17.74±1.06 | 26.26±1.73 | 29.60±2.69 | 32.60±3.67 | 39.82±4.35 |
| Percent body fat (PBF %) | 18.88±2.65 | 31.12±1.04 | 29.10±1.74 | 40.90±0.74 | 28.10±4.41 | 47.28±2.81 |
| Protein (kg) | 11.00±0.64 | 7.61±0.27 | 12.72±0.86 | 8.47±0.33 | 16.6±1.63 | 8.58±0.40 |
| Fat-Free Mass (FFM, kg) | 55.18±3.04 | 38.97±1.43 | 64.30±4.11 | 43.18±1.68 | 83.50±8.07 | 43.85±1.97 |
| Minerals (kg) | 3.79±0.22 | 2.85±0.10 | 4.47±0.33 | 3.13±0.13 | 6.01±0.14 | 3.08±0.14 |
| Soft Lean Mass (SLM, kg) | 52.05±2.86 | 36.6±1.36 | 60.62±3.83 | 40.55±1.57 | 78.60±1.61 | 41.35±1.88 |
| Visceral Fat Level (VFL) | 5.00±1.22 | 7.57±0.75 | 11.40±1.17 | 14.69±0.32 | 13.00±0.68 | 17.50±1.66 |

[1]SMM-skeletal muscle mass, BFM-Body fat mass, PBF-percent body fat, FFM-Fat free mass, SLM-Soft lean mass, and VFL-Visceral fat level. [2]Values are means ± SD. [3]Percentage of male participant (n=18).[4] Percentage of female participant (n=30)

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**Table 3: Correlation between body fat mass, visceral fat, total body water and skeletal muscle mass of various body segments measured at BIA Impedance at 250 kHz (Z (Ω))**

| Body Composition Parameter | Body Fat Mass (kg) (BFM) | Visceral Fat Level (VFL) | Total Body Water (L) (TBW) | Skeletal Muscle Mass (kg) (SMM) |
|---|---|---|---|---|
| | ***P* (*P*erson correlation)** | | | |
| Impedance | 250 kHz | | | |
| Right Arm (RA) | -0.386**[1] | -0.274 | -0.784** | -0.658** |
| Left Arm (LA) | -0.049** | -0.299*[2] | -0.799** | -0.662** |
| Trunk (TRK) | -0.435** | -0.273 | -0.579** | -0.435** |
| Right Leg (RL) | -0.585** | -0.413** | -0.626** | -0.527** |
| Left Leg (LL) | -0.587** | -0.420** | -0.607** | -0.514** |

[1]Correlation is significant at the 0.01 level (2-tailed). [2]Correlation is significant at the 0.05 level (2-tailed)

**Table 4**: **Pearson correlation between Impedance segmental analysis at 250 kHz and Segmental fat Analysis**[1]

| Segmental Fat (kg) (Mean±SD). Impedance (IMP) Z (Ω) | RAF (1.78±0.88) | LAF (1.81±0.88) | TRF (12.06±1.50) | RLF (3.77±1.49) | LLF (3.75±1.49) |
|---|---|---|---|---|---|
| RA (345.63 ± 67.27) | -0.298**[2] | -0.296** | -0.427** | -0.248 | -0.248[3] |
| LA (354.39 ± 69.14 | -0.324** | -0.320** | -0.442** | -0.385** | -0.385** |
| TR (20.54 ± 3.04) | -0.412** | -0.416** | -0.382** | -0.385** | -0.385** |
| RL (254.79 ± 51.81) | -0.536** | -0.539** | -0.481** | -0.517** | -0.516** |
| LL (254.4±52.41) | -0.540** | -0.542** | -0.488** | -0.517** | 0.516** |

[1]RAF: right arm fat, LAF: left arm fat, TRF: trunk fat, RLF: right leg fat, LLF: left leg fat, RA: right arm Impedance, LA: left arm Impedance, TR: trunk Impedance, RL: right leg Impedance and LL: left leg Impedance
[2]**Correlation is significant at the 0.01 level (2-tailed). [3]Correlation was not significant at the 0.05 level (2-tailed)

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**Table 5**: **Associations between body mass index (BMI) and body composition parameters (BCP)**

| **BCP**[1] | **BMI (Kg/m²)** | | | | | | *P*[2] | ***Eta*[3] |
|---|---|---|---|---|---|---|---|---|
| | **18.5-24.9** | | **25-29.9** | | **>30** | | | |
| | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | | |
| Body fat mass (BFM, kg) | 13.10±2.46 | 17.74±2.20 | 26.26±1.73 | 29.6±0.67 | 32.6±3.67 | 39.82±4.35 | 000 | 0.875 |
| Total body water (TBW, L) | 40.37±2.20 | 28.51±1.06 | 47.12±2.93 | 31.56±1.23 | 60.90±5.85 | 32.24±4.35 | 0.151 | 0.114 |
| Visceral fat level (VFL) | 5.00±1.22 | 7.57±0.75 | 11.4±1.17 | 14.69±0.32 | 13.0±1.57 | 17.5±1.66 | 000 | 0.655 |
| Waist circumference (WC, cm) | 83.55±4.43 | 79.84±2.03 | 103.3±4.08 | 95.16±1.25 | 112.3±4.02 | 99.9±4.09 | 000 | 0.568 |
| Waist/Hip ratio (W/H) | 0.88±0.03 | 0.88±2.03 | 0.98±0.03 | 0.94±0.01 | 0.94±0.04 | 0.89±006 | 0.003 | 0.530 |
| Soft lean mass (SLM, kg) | 52.05±2.86 | 36.0±1.36 | 60.62±3.83 | 40.56±1.57 | 78.6±0.04 | 41.35±1.88 | 0.151 | 0.342 |
| Skeletal muscle mass (SMM, kg) | 31.12±1.91 | 20.98±0.84 | 46.67±9.07 | 23.58±0.98 | 48.2±4.91 | 24.05±1.16 | 0.265 | 0.299 |

[1]Body Composition Parameters; BFM: Body fat mass, TBW: Total body water, VFL: Visceral fat level, WC: waist circumference, W/H: Waist-to-Hip ratio, SLM, Soft lean mass, and SMM, skeletal muscle mass
[2]*Pearsons* correlation is significant at the 0.01 level ($P<0.01$) or the 0.05 level ($p<0.05$).[3] Eta measurement of association and effect size

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