Body Composition and Bioelectrical Impedance Analysis-Derived Raw Variables in Pole Dancers

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BODY COMPOSITION AND BIOELECTRICAL IMPEDANCE ANALYSIS-DERIVED RAW VARIABLES IN POLE DANCERS

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ABSTRACT

Background: Pole dance is a type of functional training whose effects on body composition have been only poorly explored. Bioelectrical impedance analysis (BIA) is a field method to estimate fat-free mass (FFM), fat mass (FM), etc. In addition, of particular interest for athletes, raw BIA variables such as impedance ratio =IR (between impedance-Z at high frequencies and Z at low frequencies) and phase angle (PhA) may be considered as promising markers of muscle quality since they are related to body cell mass (BCM) and the ratio between extracellular water and intracellular water.

The aim of the study was to evaluate the effect of pole dancing training on body composition and especially on IR and PhA of the whole body, upper limbs and lower limbs.

Methods: Forty female pole dancers (age 27.4±5.1 years, body weight 57.0±6.9 kg, body mass index-BMI 22.2±2.3 kg/m²) and fifty-nine control young women (26.8±4.7 years, 58.6±6.4 kg, BMI 22.3±1.8 kg/m²) participated in the study. BIA was performed on the whole body, upper limbs and lower limbs at 5-50-100-250 kHz. FFM, FFM index (FFMI), FM and percentage of FM (%FM) were then predicted. Raw BIA variables were also considered: IR and PhA, and also bioelectrical impedance indexes (BI-indexes=stature²/Z, related to body water compartments). Arm muscle area (AMA) and arm fat area (AFA) were calculated from triceps skinfold and arm circumference.

Results: Compared to controls pole dancers exhibited higher FFM index and BI indexes at low and high frequencies as well as lower percentage of FM. Whole-body BI indexes correlated with AMA but not with AFA. PhA was greater and IRs were smaller in pole dancers than controls for the whole body and more markedly for upper limbs, whereas there were no differences for lower limbs.

When considering training level, professional and amateur pole dancers did not differ with respect to body weight and BMI. After adjusting for weight, FFM and FFMI were greater in the more trained than in the less trained group, while FM and %FM were smaller. Whole-body PhA and IRs as well as BI indexes tended to be higher in the professionals than amateurs, with much more significant differences in upper limb PhA and IRs.

Conclusions: Pole dance training has a significant effect, possibly depending also on training level, not only on FFM and FM, but also on those raw BIA variables that may be considered as markers of muscle quality.

Key words

Bioelectrical impedance analysis, muscle quality, phase angle, impedance ratio, pole dance

INTRODUCTION

Pole dance is a type of functional training that involves the use of a vertical pole to perform exercises and figures. A pole class, i.e a training session, lasts between 60 to 90 minutes (possibly depending on training level) and can be divided into three parts: warm-up and strengthening exercises are performed first, then the specific tool figures are studied, with an increasing degree of difficulty of execution, in conclusion cool down exercises close the session. The pole dancing class may be classified as a moderate-intensity cardiorespiratory endurance exercise which, if practiced regularly, leads to a significant increase in aerobic capacity, resistance, flexibility and motor coordination [1,2].

To the best of our knowledge, to date only a single study has evaluated body composition (BC) in female pole dancers, attributing to the more experienced athletes an increase in postural strength and stability, but no changes in body composition [3]. Looking at similar sports, rhythmic gymnasts show lower body weight, body mass index (BMI) and skinfold thickness compared to other athletes [4], while gymnasts have a fat-free mass (FFM) comparable to controls with the same BMI, but a reduced percentage of fat mass (%FM) [5,6]. Similarly, dancers presented similar %FM, but higher levels of FFM and muscle mass than controls whereas low values of FFM and fat mass (FM) were observed in the case of underweight athletes [7]. Finally, it is worth noting that in sedentary women a choreographed fitness group-workout contributed to reducing FM and increasing muscle mass [8].

Different methods are applied in athletes [9] to measure and track changes in body composition, but only some of them such as anthropometry and bioelectrical impedance analysis (BIA) are commonly used in the field. BIA is a widely used, non-invasive technique that measures the electrical characteristics of human body, i.e. impedance (Z) and phase angle (PhA), and also resistance (R) and reactance (Xc). Total body water (TBW), FFM and FM may be estimated by means of predictive equations including BIA variables and other variables such as age, stature and weight; of note, some equations have specifically been developed for athletes [10–12]. Recently, Sardinha et al. [12] also proposed equations based on whole-body BIA for predicting upper and lower limb lean soft tissues in sportspeople.

Using another approach to BIA data, raw variables are defined as those directly measured or computed; for instance, Z inversely correlates and bioelectrical impedance indexes (BI-indexes=stature^2/Z) directly relates to body water compartments and FFM [13,14]. Actually, the interest in applying BIA in sportspeople is further motivated by the fact that two other raw variables, impedance ratio (IR=the ratio between Z at high frequencies and Z al low frequencies) and PhA, may be both considered as promising markers of muscle quality. These variables are associated with muscle structure in terms of body cell mass (BCM) and ratio between extracellular water and intracellular water (ECW/ICW ratio) [15–17]; in addition, IR and PhA have also been related to muscle strength and physical activity [18,19]. Finally, it should be reminded that BIA may be performed on the whole body but also separately on upper limbs and lower limbs (segmental BIA), giving – at least in theory – the chance of evaluating appendicular muscle mass [20–22].

As reported in a recent systematic review [23], it is still to be defined to what extent PhA varies between different sports and with training/un-training. Some studies have shown that mean whole-body PhA is higher in athletes vs. controls, while to the best of our knowledge no data so far are available on IRs in sportspeople and only few on segmental BIA [21–23].

Against this background, the aim of the study was to evaluate the effect of pole dancing training on body composition in amateur and professional athletes compared to controls, with a particular interest for raw BIA variables that are expected to be markers of muscle quality. In addition, segmental BIA evaluation was performed to explore the bioelectrical characteristics of upper or lower limbs.

METHODS

Forty female pole dancers and fifty-nine control young women participated in the study. Pole dancers were recruited among those going to two gyms in Naples (participation rate 89%) and were amateurs (n=33), who trained 2-4 h a week in two sessions (18-36 months of specific training), and professionals (n=7) who were pole dance trainers (at least 60 months and more than 6 h a week of specific training). Controls were recruited among the female students attending the "Federico II" University of Naples. Controls were sedentary women or practiced a light training (at most 1 h twice a week). All subjects were otherwise healthy. The Ethics Committee of the "Federico II" University of Naples approved the research protocol and subjects gave their informed consent to participate in the study.

The participants avoided physical exercise for 24 hours before the measurement session and were studied by the same operator following standard procedures.

Body weight was measured to the nearest 0.1 kg using a platform beam scale and stature to the nearest 0.5 cm using a stadiometer (Seca, Hamburg, Germany). BMI was then calculated as body weight (kg)/stature^2 (m^2).

Mid-arm circumference and triceps skinfold thickness (Holtain skinfold caliper) were measured on both body sides and subsequently arm muscle area (AMA), corrected for bone area, and arm fat area (AFA) were calculated [24].

Concerning BIA, Z and PhA were determined on both body sides at 5, 50, 100 and 250 kHz (HUMAN IM TOUCH multi-frequency analyzer, DS MEDICA, Milan, Italy) in standardized conditions: ambient temperature between 23-25 °C, fast >3 h, empty bladder, and supine position for 10 min. Subjects were asked to lie down with their legs and arms slightly abducted to ensure no contact between body segments. The measuring electrodes placed on the anterior surface of the wrist and ankle, and the injecting electrodes placed on the dorsal surface of the hand and the foot, respectively. Segmental BIA has been performed using a six-electrode technique according to Organ [25].

BI index was calculated for the whole body as stature² divided by Z, as marker of ECW (Z at low frequency: 5 kHz) and FFM (Z at high frequencies: 50, 100 or 250 kHz). In addition, two other raw variables were measured for the whole body and upper or lower limbs separately: 1) IR between Z at high frequency and Z at low frequency, with three ratios: Z 50 kHz/Z 5 kHz (IR50/5), Z 100 kHz/Z 5 kHz (IR100/5), and Z 250 kHz/Z 5 kHz (IR250/5); 2) PhA measured at 50 kHz. In all cases, mean values for right and left body sides were considered for statistical analysis. For instance, upper-limb PhA is the mean of the values obtained for dominant (D) and non-dominant (ND) sides.

FFM was estimated using the Sun equation, which included stature, weight and resistance (derived from Z) as predictors [26]. FM was calculated as the difference between body weight and FFM.

Statistical analysis

Results are expressed as mean±standard deviation. Statistical significance was predetermined as $p<0.05$. All statistical analyses (one-way analysis of variance, partial correlation, general linear model) were performed using the Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, USA) version 26.

RESULTS

The general characteristics of the study groups are summarized in Table 1. Although there were no differences in body weight and BMI, pole dancers exhibited higher FFMI (16.9±1.1 vs. 16.4±0.8 kg/m², $p=0.007$) and lower %FM compared to controls (23.2±4.7 vs. 26.3±4.4%, $p=0.001$). Correspondingly, AMA was significantly greater and AFA smaller in the pole dance group than in the control group for both body sides (Table 1).

As far as raw BIA variables are concerned, whole-body and upper limb Z values were lower in the pole dancers; for instance, Z at 250 kHz was 485±50 vs. 519±38 kHz and 240±28 vs. 271±20 kHz, respectively ($p<0.001$). Furthermore, Table 2 indicates that BI indexes at 5, 50, 100 and 250 kHz were higher in the pole dancers than controls (+4.3%, +4.9%, +5.3% and +5.3%, respectively). These differences in mean values of Z and BI indexes persisted after adjustment for age and weight (data not shown). Whole-body BI indexes were correlated with AMA ($r>0.450$ for 50, 100 and 250 kHz vs. $r=0.416$ for 5 kHz) but not with AFA.

There was no significant association of PhA or IRs with stature, weight, BMI, FFM, FM, AMA and BI-indexes ($p>0.20$, data not shown). On the other hand, a moderate association emerged between upper limb and lower limb values of PhA ($r=0.463$), IR50/5 ($r=0.538$), IR100/5 ($r=0.531$) and IR250/5 ($r=0.514$). As shown in Table 2, PhA was greater in pole dancers than controls by 3.8% for the whole body ($p=0.063$) and 10.7% for upper limbs ($p<0.001$), whereas there was no difference for lower limbs. In reverse direction, smaller IRs were observed in the pole dance than in the control group for the whole body and again especially for upper limbs (Table 2).

With respect to training level, professional and amateur pole dancers did not differ with respect to body weight (55.6±4.2 vs 57.3±7.3 kg) and BMI (22.0±2.3 vs 22.2±2.3 kg/m²). After adjusting for weight, FFM (mean±SEM, 45.3±0.6 vs. 43.7±0,3 kg, $p=0.024$) and FFMI (17.7±0.3 vs. 16.9±0.1 kg/m², 0=0.014) were greater in the more trained than in the less trained athletes, while FM and %FM were smaller (12.7±0.6 vs.14.3±0.3 kg, $p=0.024$, and 21.4±11.1 vs. 24.2±0.5%, $p=0.023$, respectively).

BI indexes at different frequencies tended to be higher ($p<0.10$) in the professional than amateur athletes (+6.7% at 100 kHz and +7.4% at 250 kHz) and the same was true for whole-body PhA and IRs (Table 3). These differences persisted after adjusting for age and weight (data not shown). Concurrently, as shown in Figure 1, the professional pole dancers had greater upper limb PhA and smaller IRs, A significant greater PhA and smaller IRs were still observed in amateur athletes compared to controls p=0.041) and lower IRs (for instance, IR250/5 0.753±0.018 vs. 0.772±0.018, p<0.001).

DISCUSSION

The findings of the present study support the idea that BIA may represent a valuable approach to assess body composition in athletes, showing that pole dance training has a significant effect not only on FFM and FM, but also on those raw BIA variables that may be considered as markers of muscle quality.

Pole dance is a type of functional training that involves the use of a vertical pole to perform exercises and figures with a pole class lasting between 60 to 90 minutes (possibly depending on training level) [1]. The effects of this sport on body composition so far have been poorly explored [3].

BIA is widely used in athletes to measure and track changes in body composition [9,11]. Actually, this technique measures the electrical characteristics of human body, while body composition is then estimated by means of predictive equations including BIA data and other variables such as age, stature and weight.

A relatively small but significant effect of pole dance training on body composition first came out: despite having similar body weight and BMI, athletes showed a substantial increase of FFM (from BIA) and AMA, and also a reduction in FM, %FM and AFA compared to controls. These findings matched those reported in previous studies which showed slightly greater FFM and smaller FM in female gymnasts and dancers [4–6], while the paper by Nawrocka et al. [3] on body composition of pole dancers did not include a control group.

As a new approach, the use of raw BIA variables (BI index, PhA and IR) in the assessment of body composition has been gaining much interest. In such a case, no predictive equations are used. First, it well known that BI-indexes are directly correlated with body water compartments and FFM; our findings show that BI indexes were greater in the pole dancers than controls thus suggesting increased ECW (values at low frequency) and TBW (high frequency). Interestingly, whole-body BI indexes at high frequencies (weaker at low frequency) were correlated with AMA (r>0.450) but not with AFA.

Secondly, the interest in raw BIA variables is even more clearly motivated in sportspeople by the fact that both PhA and IR are promising markers of muscle quality. As a matter of fact, these variables are associated with muscle structure in terms of BCM and ECW/ICW ratio [15,16]; in addition, PhA has been related to muscle strength and physical activity [17-19]. Indeed, it is still to be defined to what extent PhA and/or IR varies between different sports and with training/un-training [23]. Only a few studies have shown that mean whole-body PhA is higher in athletes vs. controls, while to the best of our knowledge no data so far are available on IRs in sportspeople [23].

Our results show that whole-body PhA was significant higher in pole dancers compared to controls, with a relatively little difference between groups for the whole body. A possible explanation for this finding is that a marked increase in PhA should be due to a rise in muscle volume and hypertrophy (i.e. BCM), which was not so evident in the athletes we studied. Being inversely related to PhA, IRs were smaller in the pole dance compared to the control group for the whole body and again more clearly for upper limbs with no variations for lower limbs. To the best of our knowledge, these are the first comprehensive data on IRs in sportspeople. A first glance, the differences in IRs were small in percentage terms; indeed, the standard deviations observed for those variables were very little. For instance, for the whole body the difference of IR250/5 was 0.007, while the pooled standard deviation was 0.019.

Segmental BIA is performed on upper limbs and lower limbs separately, giving – at least in theory – the chance of evaluating segmental muscle mass [20-22]. Few previous papers have performed this type of measurements, showing for instance a more marked difference for lower than upper limbs in female volleyball players [21]. Our study yielded significant results: as a matter of fact, lower limb PhA and IRs did not differ between groups, while a marked difference emerged for upper limbs, but not for lower limbs, suggesting more marked and specific effects of pole dancing training on those muscle groups.

Another point of interest was to evaluate whether body composition varied due to different training levels. Although the group of professional athletes was small, some stimulating findings emerged: compared to amateurs they had not only greater FFM and smaller FM, but also higher PhA and lower IRs for the upper limbs, suggesting a relationships between workout volume and bioelectrical characteristics of muscle mass to be further explored in the future. Indeed, a significant greater PhA and smaller IRs were still observed in amateur athletes compared to controls (Figure 1).

Athletes and controls were studied in standardized conditions by a single experienced operator, while BIA was performed on both body sides to ensure a more reliable assessment of the bioelectrical characteristics of the body. A large proportion of the pole dancers going to two different gyms participated in the study while control women were selected among those enrolled in a study on university students who had a low physical activity.

Indeed, there are certain limitations to the study that should be considered. It was a single-center cross-sectional study in which body composition was evaluated by means of field methods and not using a criterion method. Anyway, we specifically focused on whole-body and segmental assessment of raw BIA variables, while some interesting findings also emerged with respect to FFM and FM. Furthermore, it was not possible to carry out a very accurate evaluation of strengthening or conditioning workout volume and relating this sort of data to PhA and IRs. Again, interesting differences emerged indeed between the two training levels as defined by weekly training time.

CONCLUSION

In conclusion, pole dance training has a significant effect not only on FFM and FM, but also on those raw BIA variables that may be considered as markers of muscle quality. Differences in PhA and IRs strongly suggest modifications in muscle structure, probably due to increased BCM, that seem to be more marked for the upper limbs and in professional than amateur athletes.

The promising findings of the present study, which indeed specifically focus on pole dance training, support the idea that BIA may represent a valuable technique to assess body composition in athletes, and that this approach might be useful to define the structural quality of different muscle groups. Further studies, especially the intervention ones, are needed to define the best approach to use BIA in order to measure and track changes in body composition in different sports.

Abbreviations

BIA: Bioelectrical impedance analysis

FFM: Fat free mass

FM: Fat mass

IR: Impedance ratio

Z: Impedance

PhA: Phase angle

BCM: Body cell mass

BMI: Body mass index

FFMI: Fat free mass index

%FM: percentage of fat mass

BI-index: Bioelectrical impedance index

AMA: Arm muscle area

AFA: Arm fat area

BC: Body composition

R: Resistance

Xc: Reactance

TBW: Total body water

ECW: Extracellular water

ICW: Intracellular water

D: Dominant

ND: Non dominant

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Ethics approval and consent to participate

The Ethics Committee of the "Federico II" University of Naples approved the research protocol and the study was conducted in accordance with the Declaration of Helsinki. All participants gave written informed consent prior to being enrolled in the study.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflict of interests.

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Author's contributing

G. Ballarin, F. Monfrecola, A.Bianco collected the data. G. Ballarin, P. Alicante, M. Marra analyzed data. G. Ballarin, L. Scalfi, A.M. Sacco and M. Marra designed the study and wrote the manuscript. A.M. Sacco supervised the project. All authors discussed the results and commented on the manuscript. The authors read and approved the final manuscript.

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Table 1: individual characteristics and body composition in pole dancers and controls.

	Pole dancers (n. 40)	Controls (n. 59)	p value
Age (yrs)	27.4±5.1	26.8±4.7	0.561
Weight (kg)	57.0±6.9	58.6±6.4	0.225
Stature (cm)	160.3±5.1	161.9±4.9	0.139
BMI (kg/m²)	22.2±2.3	22.3±1.8	0.747
Fat-free mass (kg)	43.5±3.5	43.0±3.1	0.448
Fat-free mass index (kg/m²)	16.9±1.1	16.4±0.8	0.007
Fat mass (kg)	13.5±4.3	15.6±4.1	0.013
Percentage of FM (%)	23.2±4.7	26.3±4.4	0.001
Arm muscle area, D (cm²)	52.5±9.4	48.9±8.9	0.060
Arm fat area, D (cm²)	2.0±0.5	2.2±0.8	0.047
Arm muscle area, ND (cm²)	51.8±10.4	48.0±8.4	0.045
Arm fat area, ND (cm²)	2.0±0.6	2.2±0.7	0.098

mean±standard deviation
BMI=body mass index
Fat-free mass estimated from BIA; arm muscle area corrected for bone area
D=dominant side and ND= non dominant side of the body

Table 2: bioimpedance indexes, impedance ratios and phase angles measured on the whole body, upper and lower limbs in pole dancers and controls.

	Pole dancers (n. 40)	Controls (n. 59)	p value
WHOLE BODY			
BI index 5 kHz (ohm)	41.1±4.2	39.4±3.8	0.043
BI index 50 kHz (ohm)	46.8±4.9	44.6±4.1	0.018
BI index 100 kHz (ohm)	49.7±5.3	47.2±4.3	0.013
BI index 250 kHz (ohm)	53.5±5.7	50.8±4.6	0.011
IR Z 50/Z 5 kHz	0.878±0.014	0.883±0.014	0.060
IR Z 100/Z 5 kHz	0.827±0.017	0.835±0.017	0.039
IR Z 250/Z 5 kHz	0.768±0.018	0.775±0.018	0.058
PhA at 50 kHz (degrees)	6.07±0.56	5.85±0.56	0.063
UPPER LIMBS			
IR Z 50/Z 5 kHz	0.887±0.013	0.897±0.015	<0.001
IR Z 100/Z 5 kHz	0.837±0.016	0.852±0.018	<0.001
IR Z 250/Z 5 kHz	0.769±0.019	0.783±0.020	<0.001
PhA at 50 kHz (degrees)	5.27±0.59	4.76±0.56	<0.001
LOWER LIMBS			
IR Z 50/Z 5 kHz	0.867±0.018	0.865±0.018	0.451
IR Z 100/Z 5 kHz	0.816±0.022	0.814±0.021	0.718
IR Z 250/Z 5 kHz	0.771±0.025	0.769±0.024	0.765
PhA at 50 kHz (degrees)	7.05±0.70	7.06±0.69	0.974

mean±standard deviation

BI index=bioimpedance index; IR=impedance ratio; PhA=phase angle

Table 3: Bioimpedance index, impedance ratio and phase angle measured on the whole body, upper and lower limbs in amateur and professional pole dancers.

	Professional pole dancers (n. 7)	Amateur pole dancers (n. 33)	p value
WHOLE BODY			
BI index 5 kHz (ohm)	42.8±2.9	40.6±4.4	0.214
BI index 50 kHz (ohm)	49.2±3.9	46.3±5.0	0.113
BI index 100 kHz (ohm)	52.4±4.3	49.1±5.3	0.091
BI index 250 kHz (ohm)	56.7±4.9	52.8±5.7	0.069
IR Z 50/Z 5 kHz	0.869±0.015	0.879±0.014	0.079
IR Z 100/Z 5 kHz	0.817±0.018	0.830±0.016	0.072
IR Z 250/Z 5 kHz	0.756±0.021	0.771±0.018	0.058
PhA at 50 kHz (degrees)	6.37±0.57	6.00±0.55	0.117
UPPER LIMBS			
IR Z 50/Z 5 kHz	0.875±0.010	0.889±0.013	<0.001
IR Z 100/Z 5 kHz	0.824±0.014	0.840±0.015	<0.001
IR Z 250/Z 5 kHz	0.753±0.018	0.772±0.018	<0.001
PhA at 50 kHz	5.14±0.54	4.61±0.53	0.041
LOWER LIMBS			
IR Z 50/Z 5 kHz	0.863±0.021	0.868±0.018	0.463
IR Z 100/Z 5 kHz	0.810±0.025	0.817±0.021	0.435
IR Z 250/Z 5 kHz	0.763±0.030	0.772±0.025	0.355
PhA at 50 kHz (degrees)	7.11±0.80	7.04±0.70	0.821

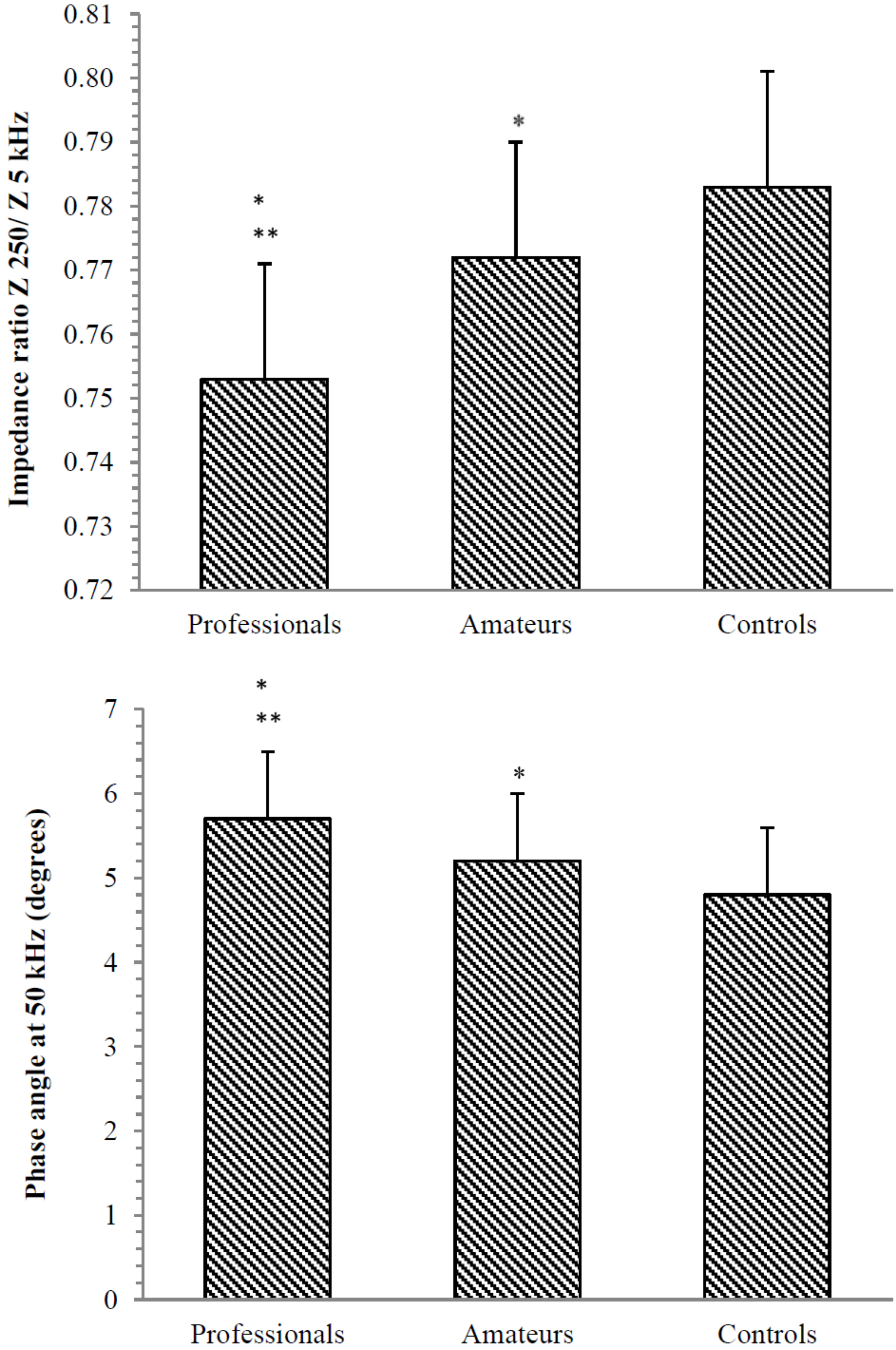
mean±standard deviation

BI index=bioimpedance index; IR=impedance ratio; PhA=phase angle

LEGEND TO THE FIGURE 1

Impedance ratio (Z250 kHz/Z 5 kHz) and phase angle at 50 kHz in amateur or professional pole dancers compared to control women.

Figure 1



* vs controls $p<0.05$
** vs amateurs $p<0.05$

Figures

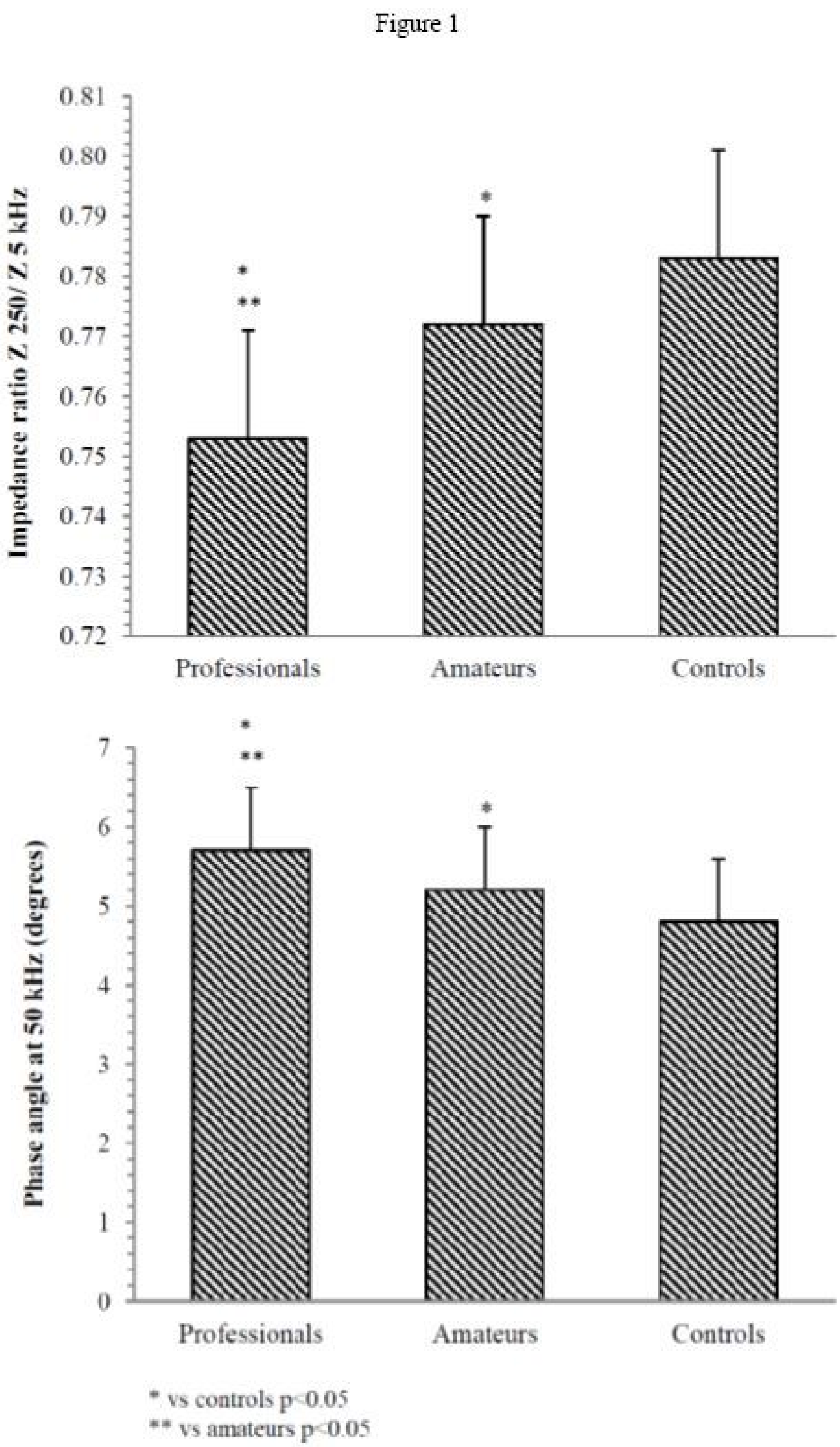


Figure 1

Impedance ratio (Z250 kHz/Z 5 kHz) and phase angle at 50 kHz in amateur or professional pole dancers compared to control women.