# Raw Bioelectrical Impedance Analysis (BIA) Variables and Physical Fitness in Semi-Professional Basketball Players

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Keywords: Basketball, Physical Fitness, Body Composition, BIA, Phase Angle, Impedance Ratio.

Abstract: Body composition (BC) and physical performance are routinely assessed in athletes. Incomplete data are available on BC and its relationships with physical fitness in basketball players. Our study aimed to evaluate differences in raw BIA variables such as impedance ratio=IR and phase angle=PhA, and their relationships with physical fitness in semi-professional male basketball players compared to controls. Fourteen basketball players (age 21.9±5.3 years, body weight 84.6±11.3 kg, body mass index=BMI 24.6±2.0 kg/m²) and fifty-seven control men (age 22.6±2.0 years, body weight 75.1±9.4 kg, BMI 24.1±2.3 kg/m²) participated in the study. BC was assessed using bioelectrical impedance analysis (BIA) and physical fitness using handgrip strength (HGS), long jump (L-J), squat jump (SQ-J) and counter-movement jump (CM-J). PhAs were higher and IRs were lower in basketball players for the whole body and limbs. Differences in HGS between groups did not persist after adjusting for body weight, whereas L-J (+32.6%), SQ-J (+35.4%) and CM-J (+28.7%) were clearly higher in the basketball group. HGS, L-J, SQ-J and CM-J significantly correlated with both IRs and PhAs (whole body and limbs). In conclusion, this study shows that raw BIA variables were significantly different in semi-professional basketball players compared to controls and also exhibit significant relationships with physical fitness.



## 1 INTRODUCTION

The evaluation of physical fitness and body composition (BC) is crucial in assessing athletes' performance. In basketball players $VO_2$max, long jump and shuttle-run test have been evaluated with the aim to identify talents or design training programs (Tsunawake et al. 2003; Calleja González et al. 2018). For instance, a difference has been observed in BC, aerobic fitness, anaerobic power, and vertical jump among positional roles (Ostojic et al. 2006; Ponce-González et al. 2015). Indeed, there is some conflicting evidence (Mancha-Triguero et al. 2019): vertical jump height was around or greater than 60 cm in the study by Ostojic et al. (2006), but much lower in other studies (Ponce-González et al. 2015).

As far as BC is concerned, previous papers have shown high fat-free mass (FFM) and low fat mass (FM) in both male and female basketball players (Fields et al. 2018a). FM was similar in high school and elite female players (Tsunawake et al. 2003), whereas female adolescents practicing basketball or other team sports had more lean body mass and less FM than controls (Ubago-Guisado et al. 2017). No significant seasonal differences were observed, but male players showed an increase in FFM across years (Fields et al. 2018b) and female players a reduced body fat (Stanforth et al. 2014). A low percentage of body fat was found at higher playing levels and a wide variability of skinfold thickness was observed among different playing positions (Vaquera et al. 2015).

BC has been evaluated in basketball players with different techniques such as DXA, air pletismography and hydrostatic weighing. (Hoare 2000; Vaquera et al. 2015; Fields et al. 2018b; Raymond-Pope et al. 2020). Skinfold thickness measurement and bioelectrical impedance analysis (BIA) are the most commonly technique used in the field . On the other hand, only few studies evaluated BC in basketball players using bioimpedance analysis=BIA (Nescolarde et al. 2011; Gerodimos et al. 2017). Our interest was further stimulated by the fact that raw BIA variables such as impedance ratio (IR as ratio between impedance=Z at high frequency and Z at low



Ballarin, G., Monfrecola, F., Alicante, P., Di Gregorio, A., Marra, M., Sacco, A. and Scalfi, L.
Raw Bioelectrical Impedance Analysis (BIA) Variables and Physical Fitness in Semi-Professional Basketball Players.
DOI: 10.5220/0010066101330138
In *Proceedings of the 8th International Conference on Sport Sciences Research and Technology Support (icSPORTS 2020)*, pages 133-138
ISBN: 978-989-758-481-7

frequency) or phase angle (PhA) may be considered as promising markers of muscle quality. As a matter of fact, these raw BIA variables have been related to muscle structure (body cell mass=BCM) and the ratio between extracellular water=ECW and intracellular water=ICW in different pathophysiological conditions (Lukaski et al. 2017) and also in athletes (Di Vincenzo et al. 2019). In addition, IR and PhA have been associated with muscle function in various diseases (de Blasio et al. 2019; Mundstock et al. 2019), but not in athletes (Di Vincenzo et al. 2019).

Finally, the relationship between physical fitness and BC has been evaluated in few previous studies in male athletes: no or a weak correlation emerged between vertical jump or standing broad jump performance and stature (Davis et al. 2003; Sidhu 2018), whereas there was a stronger relationship between vertical jump and lower percentage of body fat (Davis et al. 2003; Aouadi et al. 2012). No data are available on the association between physical fitness and raw BIA variables.

Based on previous literature, basketball training might be expected to influence muscle quality. It might be supposed that raw BIA variables differ between semiprofessional basketball players and controls and that there are significant relationships between these variables and physical fitness.

Facing this background, we aimed to evaluate in semi-professional basketball players vs. controls: 1) differences in raw BIA variables (whole body and limbs); 2) differences in physical fitness; 3) relationships between physical fitness and raw BIA variables.

# 2 METHODS

This cross-sectional study included fourteen male semi-professional basketball athletes (age 21.9±5.3 years, stature 185.1±7.1 cm, body weight 84.6±11.3 kg, BMI 24.6±2.0 kg/m²) and fifty-seven control men (age 22.6±2.0 years, stature 176.1±7.7 cm, body weight 75.1±9.4 kg, BMI 24.1±2.3 kg/m²). Basketball players were semi-professional athletes (A.S.D. Folgore Nocera basketball team), who competed in the Italian fifth division championship (C-silver). Athletes trained at least six hours a week in three sessions and played a match every week. Every training session lasted at least 120 minutes and can be considered as a moderately hard training program. Controls were recruited among the students attending the Federico II University of Naples. Controls did not practice sport and did less than 100 minutes of moderate-vigorous activity. All subjects were otherwise healthy.

The participants avoided physical exercise for 24 hours before the measurement session, being 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). Body mass index=BMI was then calculated as body weight (kg)/stature² (m²).

Concerning BIA, Z and PhA were measured at frequencies between 5 and 300 kHz (HUMAN IM TOUCH analyser, DS MEDICA, Milano), in standardized conditions: ambient temperature between 23-25 °C, fast >3 h, empty bladder, and supine position for 10 min. BIA data for the whole body and separately for upper limbs and lower limbs were taken into consideration with respect to: 1) bioimpedance index=BI index, calculated as stature² divided by Z at 5 or 300 kHz, as marker of ECW and total body water=TBW or FFM, respectively; 2) IR between Z at high frequency and Z at low frequency (three ratios: Z 50 kHz/Z 5 kHz, Z 100 kHz/Z 5 kHz, and Z 300 kHz/Z 5 kHz); 3) PhA measured at 50 kHz. In all cases, mean values for right and left body sides were considered for statistical analysis.

FFM was estimated using the Sun equation, which included stature, body weight and resistance (very close to Z) as predictors (Sun et al. 2003). Fat mass (FM) was calculated as body weight minus FFM.

## 2.1 Fitness Tests

Selected physical fitness tests were performed according to standard procedures with respect to:

1) Handgrip strength (HGS) to measure isometric strength of upper limbs (Dynex dynamometer, MD systems Inc., Ohio USA). Maximum values of six attempts on preferred and non-preferred sides of the body were used for statistical analysis.

2) Long jump (L-J) to assess lower body muscle strength. Participants performed a two foot take-off and landing. The swinging of the arms and flexing of the knees are permitted to provide forward drive. The subject attempts to jump as far as possible, landing on both feet without falling backwards. Length was measured to the nearest point of contact on the landing. Two attempts were performed and the best value was used for analysis.

3) Squat jump (SQ-J) and countermovement jump (CM-J) (OptoJump device, MicroGate, Italy) to assess the explosive power of lower limbs. Subjects performed SQ-J with hands placed on the hips, while CM-J has been performed with arm swinging. In both

cases, the highest of three jumps was used for statistical analysis.

## 2.2 Statistical Analysis

Results are expressed as mean±standard deviation. Statistical significance was pre-determined as $p<0.05$. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, USA) version 24.

Shapiro-Wilk test was applied to assess normality of the sample. The general linear model was used to assess differences after controlling for body weight. One-way ANOVA was performed to assess differences between the two groups. Partial correlations were employed to evaluate association between variables after controlling for group and age.

# 3 RESULTS

The general characteristics of the study groups are reported in Table 1. As expected, basketball players were taller and heavier than controls, with no statistical difference for age and BMI. They also exhibited higher FFM (from BIA, $p<0.01$), but there was no difference after adjusting for body weight.

Table 1: Individual characteristics and body composition in 14 basketball players and 57 controls.

| | | Basketball players | Controls |
|---|---|---|---|
| Age | yrs | 21.9±5.3 | 22.6±2.0 |
| Body weight | kg | 84.6±11.3 | 75.1±9.4[a] |
| Stature | cm | 185.1±7.1 | 176.1±7.7[a] |
| Body mass index | kg/m$^2$ | 24.6±2.0 | 24.1±2.3 |
| Fat-free mass | kg | 66.8±6.3 | 60.5±6.7[a] |
| Fat mass | kg | 17.8±6.5 | 14.8±5.0 |
| Fat mass | % | 20.5±5.5 | 19.4±4.9 |

mean±standard deviation.
a=p<0.05 between groups.

As far as raw BIA variables are concerned (Table 2), BI indexes at 5, 50, 100 and 300 kHz were significantly higher in the basketball group than in the control group (+7.6%, +9.2%, +9.9% and +10.6%, respectively); no differences persisted after adjustment for body weight.

On the other hand, in basketball players PhAs were higher for the whole body, upper limbs and lower limbs (+9.8%, +8.8% and +9.2% respectively) (Table 3).

Table 2: Bioimpedance indexes calculated for the whole body in 14 basketball players and 57 controls.

| Bioimpedance (BI) index (cm$^2$/kHz) | Basketball players | Controls |
|---|---|---|
| 5 kHz | 59.2±6.0 | 55.0±6.8[a] |
| 50 kHz | 70.3±6.6 | 64.4±8.3[a] |
| 100 kHz | 75.5±7.0 | 68.7±9.0[a] |
| 300 kHz | 83.7±7.4 | 75.7±9.9[a] |

mean±standard deviation.
a=p<0.05 between groups.

In the opposite direction, significant lower IRs were observed in the basketball group compared to the control group for the whole body and lower limbs ($p<0.10$ for upper limbs). This was true for each of the three ratios considered (data shown for IR Z 300 kHz/Z 5 kHz).

Focusing on physical fitness, HGS was well correlated ($p<0.05$) with L-J ($r=0.505$) SQ-J ($r=0.613$) and CM-J ($r=0.641$). HGS was significantly higher in the basketball group (Table 3), but the difference was reduced after adjusting for body weight (adjusted means 48.7 kg vs 46.4 kg). On the contrary, a clear difference emerged between groups in L-J (+32.6% in basketball players), SQ-J (+35.4%) and CM-J (+28.7%).

Table 3: Phase angle at 50 kHz and impedance ratio Z 300 kHz/Z 5 kHz measured for the whole body and limbs in 14 basketball players and 57 controls.

| | Basketball players | Controls |
|---|---|---|
| Impedance ratio | | |
| Whole body | 0.707±0.025 | 0.727±0.022[a] |
| Upper limbs | 0.713±0.028 | 0.727±0.025 |
| Lower limbs | 0.713±0.025 | 0.736±0.024[a] |
| Phase angle (degrees) | | |
| Whole body | 7.52±0.82 | 6.85±0.67[a] |
| Upper limbs | 6.58±1.00 | 6.05±0.74[a] |
| Lower limbs | 8.46±0.76 | 7.75±0.70[a] |

mean±standard deviation. PhA=phase angle.
a=p<0.05 between groups.

The relationships of physical fitness with selected variables of interest were first evaluated by partial correlation (after adjusting for group and age). Table 5 shows that HGS, L-J, SQ-J and CM-J substantially correlated with IRs (each of the three ratios) and PhA measured on the whole body; similar results also come out in most cases for upper or lower limbs (data not shown). Actually, physical fitness variables were more strictly correlated with raw BIA variables than with stature, body weight or BMI. .

# 4 DISCUSSION

This study shows that raw BIA variables such as IR and PhA were significantly different in semi-professional basketball players compared to controls (suggesting improved muscle structure) and also exhibit significant relationships with physical fitness.

Table 4: Physical fitness tests performed in 14 basketball players and 57 controls.

| Performance Tests | | Basketball players | Controls |
|---|---|---|---|
| Handgrip strength | kg | 51.4±10.4 | 45.9±8.2[a] |
| Long jump | cm | 221.8±23.6 | 167.3±29.6[a] |
| Squat jump | cm | 32.9±8.2 | 24.3±5.7[a] |
| Countermovement jump | cm | 30.5±8.7 | 23.7±4.8[a] |

mean±standard deviation.
a=p<0.05 between groups.

There have been a number of studies on BC in basketball players, showing high FFM, low FM, differences depending on playing levels or playing position, etc. (Tsunawake et al. 2003; Stanforth et al. 2014; Vaquera et al. 2015; Ubago-Guisado et al. 2017; Fields et al. 2018a; Fields et al. 2018b).

BIA is a widely used, non-invasive and portable technique to assess body composition, which has been used only by few studies in basketball players (Nescolarde et al. 2011; Gerodimos et al. 2017).

In this study BIA was performed in semi-professional basketball players and controls to evaluate body composition compartments and raw BIA variables.

First, FFM was estimated by means of predictive equations that include BIA variables, age, stature and body weight (Sun et al. 2003). After adjusting for confounders, no major impact of training on FFM or FM emerged, possibly because of the characteristics of the training program.

Then, raw BIA variables such as BI index, IR and PhA were considered. BI index is not widely mentioned in the literature, although its relationships with ECW (at low frequencies) and TBW or FFM (at high frequencies) are well known. In this study whole-body BI indexes were higher in the basketball players, with a larger difference between groups at 300 kHz than 5 kHz, suggesting significant differences in body water compartments.

Table 5: Partial correlation of physical fitness with impedance ratio (IR=Z 300 kHz/Z 5 kHz) and phase angle.

| Physical fitness tests | IR* | | Phase angle | |
|---|---|---|---|---|
| | r | p | r | p |
| Handgrip strength | -0.375 | 0.002 | 0.418 | <0.001 |
| Long jump | -0.349 | 0.005 | 0.335 | 0.008 |
| Squat jump | -0.522 | <0.001 | 0.530 | <0.001 |
| Countermovement jump | -0.467 | <0.001 | 0.480 | <0.001 |

Results for the whole body (adjusted for age and group)
*Similar findings for IR 50 kHz/5 kHz or 100 kHz/5 kHz

As primary aim of the study, the attention was focused on those raw BIA variables (IR and PhA) that are markers of cell integrity and quite possibly of muscle structure and quality (Lukaski et al. 2017a; Di Vincenzo et al. 2019), being also associated with muscle strength and physical activity (de Blasio et al. 2019; Mundstock et al. 2019). Overall, evidence on IR and PhA is still lacking in athletes (Di Vincenzo et al. 2019).

PhA is believed to be a proxy of BCM (and inversely related to the ratio between ECW and ICW). PhA was significantly higher in basketball players than controls (+9.8% for the whole body), with a similar difference between groups for upper limbs and lower limbs. These observations were reinforced by data on IR, which is a proxy of the ratio between ECW and ICW (and inversely related to BCM). To the best of our knowledge, there is no consistent information on the IR of athletes. There is also no agreement on the frequencies to be used for calculating IR. For calculating IRs we selected three high frequencies (50, 100 and 300 kHz) and one low frequency (5 kHz). Our results were similar for the three ratios considered, indicating that IRs were significantly lower in the basketball players for the whole body and lower limbs (less clearly for upper limbs). At first glance, the differences in IRs appear negligible in percentage terms; actually, they should be considered in view of the very small standard deviations observed for these variables. For instance, the difference in IR Z 300 kHz/Z 5 kHz for the whole body was 0.020, which was close to the pooled SD of 0.024.

Overall, evidence on IR and PhA suggests different effects of training on distinct limb muscles with a more marked improvement in raw BIA variables for the lower limbs.

As further point, we evaluated physical fitness focusing on the domain of strength. Previous studies have already assessed physical performance, for instance $VO_2$max, in basketball players (Mancha-

Triguero et al. 2019). We select physical fitness variables that can be measured in both basketball players and controls. Unlike HGS, L-J, SQ-J and CM-J, which are all markers of lower limb strength, were clearly higher in the basketball players, with a similar relative difference between groups.

Finally, another aim of the study was to demonstrate a relationship between function and body composition as explored by raw BIA variables.

As far as we know, in athletes there are no consistent data on this topic (Di Vincenzo et al. 2019). Based on our results, the variables of physical fitness considered were all significantly correlated with IRs and PhA. It should be noted that the associations with L-J, SQ-J and CM-J were stronger for lower-limb than upper-limb IRs or PhA, while the opposite was seen for HGS. Thus, raw BIA variables might be used for a more effective evaluation of muscle quality in terms of both muscle structure and strength.

In conclusion, this preliminary study gives some information about the use of raw BIA variables in assessing the athletes' nutritional status. Actually, raw BIA variables such as IR and PhA were significantly different in semi-professional basketball players, suggesting higher BCM, and also exhibit significant relationships with physical fitness. More information may be given by segmental BIA of upper and lower limbs, which can be further useful for a better evaluation of the relationships between physical fitness and BC.

Large cross-sectional studies and, possibly, longitudinal studies are needed to confirm that the concurrent use of BIA and physical fitness tests is valuable in assessing muscle quality, and to assess differences due to gender, training volume, playing position, playing levels, etc.

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