Bio-impedance body composition comparisons between athletes and healthy subjects

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Abstract. Body composition is a useful means for athletes’ body composition assessment, relying on reference population data. This study aims at comparing body composition multifrequency impedance data of athletes and healthy adult populations. Differences were found in tissular, hydration and metabolic indices. They were significant, in the expected direction, but quite weak and additional data from reference technologies would set if specific equations are needed. The current ones are nevertheless suitable for reliable follow-up studies.

1. Introduction
Body composition follow-up is useful to athletes to help in physical preparation. Bioimpedance provides a non-invasive, economic and reliable means of measuring body composition indices. Bio-impedance body composition models rely on reference population data. Reliability of body composition indices is thus dependant on how good the measured individual’s profile fits to reference population’s. Peculiar population such as infants, elderly or athletes may need specific reference database to allow meaningful follow-ups and comparisons.

The aim of this study is to compare body composition data of athletes and reference healthy adult populations and evaluate the pertinence of building a dedicated model for athletes.

2. Materials & Methods

2.1. Subjects
Data was collected among highly trained athletes (89 men, 26 women) and a reference healthy adult population (30 men, 24 women). Athletes practiced different short and long distance sports (e.g. alpine skiing, cross-country skiing / biathlon, ski-mountaineering, running), from local to olympic level. Healthy adults’ body mass index (BMI) was lower than 30.

2.2. Measurements
Data was collected using a multifrequency (1-1000 kHz range) bio-impedance measuring device (Z-Métrix®, BioparHom, Le Bourget du Lac, France) validated by a French clinical study (n°2008-A01373-52). Raw complex electrical impedance data is computed from measured voltage caused by
injection of low intensity (77 µA max) electrical currents. It is then turned into body composition
indices using a Cole-Cole-derived model [1,2].
Indices are of three categories: tissular, hydration and metabolic. Tissular indices are fat mass (FM/W: fat on body mass ratio), lean mass (LM/W: lean on body mass ratio), and muscular mass (MMus/W: muscular on body mass ratio [3]). Hydration indices are total body water (TBW/W: total body water on body mass ratio [4]), intracellular water (ICW/TBW: intracellular on total water ratio), and extracellular water (ECW/TBW: extracellular on total water ratio). Metabolic indices are metabolic activity index (MAI [5], phase-related), body cell mass (BCM/W: body cell mass on body mass ratio [6]) and its protein content (BCM prot.content [7]), and extracellular mass (ECM/W: extracellular on body mass ratio).
Measurements were taken in upright position and on the right body side.

2.3. Analysis
Comparisons between the two populations were evaluated with unpaired Student tests with a p=.05 significance threshold.

3. Results
Comparisons results are listed in Table 1 and

Table 2. They showed tissular, hydration and metabolic differences: significantly higher MMus/W in athletes than in healthy adults in both men and women, higher LM/W and lower FM/W in women only; higher BCM/W and BCM prot. content in both genders, lower ECM/W in men only; higher TBW/W in women only, lower ICW/TBW in men only, higher ECW/TBW in both genders. Electric data showed higher reactance in athletes of both genders, and lower resistance in men only (X/H, R/H: 50 kHz reactance and resistance on height ratios).

### Table 1. Comparisons results in women.

|                  | Athletes (mean±sd) | Healthy adults (mean±sd) | Student unpaired test |
|------------------|--------------------|--------------------------|-----------------------|
| Age (years)      | 35.1±12.2          | 43.5±16.4                | t=-2.05, p=.046       |
| Height (cm)      | 165.0±7.1          | 163.3±6.5                | t=.88, p=.383, NS     |
| Weight (kg)      | 56.8±8.3           | 60.7±8.2                 | t=-1.64, p=0.108, NS  |
| BMI (kg/m²)      | 20.8±2.0           | 22.8±3.0                 | t=-2.71, p=0.009     |
| MAI              | 6.4±0.5            | 5.9±1.1                  | t=1.97, p=0.054, NS   |
| ECM/W (%)        | 35.1±3.0           | 34.6±5.4                 | t=0.46, p=0.649, NS   |
| BCM/W (%)        | 42.2±3.2           | 37.3±4.8                 | t=4.30, p<0.001      |
| BCM prot. content (%) | 11.1±0.9   | 9.7±1.3                  | t=4.34, p<0.001      |
| FM/W (%)         | 24.1±4.2           | 29.4±7.3                 | t=-3.16, p=0.003     |
| LM/W (%)         | 70.4±6.5           | 64.7±11.2                | t=2.19, p=0.033      |
| MMus/W (%)       | 35.5±2.9           | 31.3±4.1                 | t=4.22, p<0.001      |
| TBW/W (%)        | 63.0±4.8           | 58.2±6.5                 | t=2.95, p=0.05       |
| ECW/TBW (%)      | 46.0±0.8           | 44.6±1.6                 | t=4.06, p<0.001      |
| ICW/TBW (%)      | 53.3±3.2           | 54.6±6.1                 | t=-0.94, p=0.352, NS |
| X/H (Ω/m)        | 30.4±3.6           | 30.2±5.5                 | t=0.17, p=0.865, NS  |
| R/H (Ω/m)        | 271.3±27.7         | 292.4±26.8               | t=-2.70, p=0.010     |
Table 2. Comparisons results in men.

|                  | Athletes (mean±sd) | Healthy adults (mean±sd) | Student unpaired test |
|------------------|--------------------|--------------------------|-----------------------|
| Age (years)      | 37.0±10.5          | 39.8±14.3                | t= -1.15, p=0.253, NS |
| Height (cm)      | 178.5±5.8          | 176.8±6.6                | t=1.37, p=0.174, NS   |
| Weight (kg)      | 76.9±9.7           | 78.1±10.7                | t=-0.54, p=0.592, NS  |
| BMI (kg/m²)      | 24.1±2.5           | 25.0±2.9                 | t=-1.54, p=0.126, NS  |
| MAI              | 7.5±0.8            | 6.9±1.2                  | t=2.94, p=0.004       |
| ECM/W (%)        | 34.1±2.5           | 35.5±4.2                 | t=-2.16, p=0.033      |
| BCM/W (%)        | 54.3±4.0           | 51.8±4.2                 | t=2.88, p=0.005       |
| BCM prot. content (%) | 14.4±1.1       | 13.7±1.1                | t=3.04, p=0.003       |
| FM/W (%)         | 18.4±2.8           | 19.7±5.9                 | t=-1.67, p=0.097, NS  |
| LM/W (%)         | 69.7±6.6           | 69.9±7.2                 | t=-0.09, p=0.930, NS  |
| MMus/W (%)       | 49.3±3.5           | 47.0±4.0                 | t=3.04, p=0.003       |
| TBW/W (%)        | 67.2±4.9           | 68.2±5.2                 | t=-0.92, p=0.361, NS  |
| ECW/TBW (%)      | 45.3±1.2           | 43.3±1.4                 | t=7.61, p<0.001       |
| ICW/TBW (%)      | 54.2±4.2           | 56.7±4.9                 | t=-2.66, p=0.009      |
| X/H (Ω/m)        | 26.4±24.2          | 24.2±4.3                 | t=2.58, p=0.011       |
| R/H (Ω/m)        | 201.6±22.3         | 201.2±27.8               | t=0.09, p=.929, NS    |

4. Discussion

Most of these differences confirm that athletes are in a better shape than healthy adults. They show a better tissular distribution in athletes. Male athletes differ by more muscular mass; female athletes also have a more favorable fat/fat free balance.

At a metabolic level, athletes’ indices suggested a better physical working capacity as evidenced by higher BCM/W [8], and a better cellular membrane exchange capacity as evidenced by higher MAI [9]. Surprisingly, MAI was higher in female athletes than healthy ones but did not reach significance threshold. It is believed that considering parameters such as overtraining, fatigue and performance could help understanding MAI variation factors in this peculiar population [10,11]. The significant (p=.046) difference in the two women groups may also represent a bias as it is known phase angle lowers with age [12].

All groups were fairly hydrated. Intra- extracellular water balance leaned towards extracellular compartment in athletes. Their higher extracellular water is thought to help them coping with effort-related water loss.

Electrical indices such as those used for BIVA analysis (e.g.[13]) are consistent with metabolic and hydration results since resistance tends to be lower and reactance (capacitive dimension of impedance) higher.

Although differences between athletes and healthy adults were found in the expected direction, they were rather weak [14]. Separating different sports could show stronger differences. Alternatively, the model possibly skewed the indices towards median values.
5. Conclusion
Differences were found between athletes and healthy subjects at tissular, hydration and metabolic levels. An athlete-specific data base will allow displaying acute comparisons among specific reference population for individual athletes. It would be interesting to build such database for specific sports or sports type (endurance, sprint). Data from reference body composition technologies should tell if athletes’ indices were accurate, thus indicating if new equations are needed. In all cases, repeatability is not affected and follow-up studies are reliable even without it.

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