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Case study: using monitoring of body composition data obtained by bioimpedance, in training of an elite male runner

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Abstract

This study wants to investigate if multi-frequency bioimpedance analysis; which is non-invasive, quick and mobile; and its indicators can be used like a tool for helping technical staff to improve performance, by optimizing training load, specific hydration and specific nutrition of an elite male runner. The principal results of this study are that BIA monitoring allowed to explain body weight variations, to optimize hydration state and to check fatigue state during the season. To conclude, BIA might be use in sport routine in order to monitor training load, hydration and nutrition during all the season.

"Keywords: Body composition ; Bioimpedance Analysis ; Fat mass ; Hydration ; Performance"

Nomenclature

BIA	Bioimpedance Analysis	MAI	Metabolic Activity Indicator
H	Height	R	Resistances
W	Weight	X	Reactances
BMI	Body Mass Index	Re	Resistance of extracellular compartment
FM	Fat Mass	Rinf	Resistance of total body compartment
FFM	Fat-Free Mass	TBW	Total Body Water
MMus	Muscle Mass	TBW/W	Body Hydration rate
BCM	Body Cell Mass	Trimps	Training Impulse

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1. Introduction

Body composition analysis by bioimpedance (BIA) is a convenient tool as it is non-invasive, quick and mobile. Thus, it can be repeated frequently and used in sportive and clinic routine.

In trail running, training is based on specific development of aerobic qualities and may induce several modifications on body composition [1]. Theses parameters may be monitored to be useful in physical preparation.

Tissular distribution is used to estimate, in particular, Weight/Power rate. It may be modified with a decrease of Fat Mass (FM) and an increase of Muscle Mass (MMus) might be modified by training or over-reaching [2].

Hydration rate (TBW/W) may be modified by lifestyle and the lack of hydration around exercise, during training session and recovery period. This rate is often used in training because it is often considered like a limiting factor of performance [3]

Metabolic indicators might be modified by training load, advancing a fatigue or a performance increase. Varlet-Marie [4] showed that Body Cell Mass (BCM) is hardly correlated with performance in elite male sportsmen. An other parameter is Metabolic Activity Indicator (MAI) that traduces cellular exchange capacity of the subject [5].

The aim of this case study is to observe relations between BIA tissular, hydric and metabolic indicators and training data collected during the entire training session of this elite male runner. This study wants to investigate if BIA and its indicators can be used like a tool for helping technical staff to improve performance, by optimizing training load, specific hydration and specific nutrition.

2. Methods

2.1. Subject of this study.

For this study, an elite male runner was recruited, 29 years old, 1m75 and 67.8kg. He practises endurance sport since 8 years and especially trail running since 3 years. In 2009 season, he prepares 4 trails competitions and 2 ultra-trail competitions, his major objectives. He obtained the sixth place in World Championship and succeeded in the Reunion Island Grand Raid.

BIA measures were realized between November, 2008 and October, 2009. The measure was three times repeated, after 10 minutes relaxed. Height (H), weight (W), age and sex are entered manually in the software

The evolution of nutritional and hydration strategy are described in Table 1. There are also the PTP (Physical Training Period) and tapering period (decrease of training volume before a competition) [6].

Table 1: Monitoring of the athlete's physical activity.

BIA Session	Date	Training & Context	Nutritional	Hydration
BIA n°1	November, 08	Physical Training Period n°1 (**PTP n°1**): high training volume + two weeks in altitude	Intake of lot of proteins, decrease of fat intakes.	Regular intake of solid and liquid water but not sufficient
BIA n°2	February, 09	After 8 weeks training & beginning of **PTP n°2**: Specific Preparation Period – balance between Volume and Intensity	Less proteins but still no fat intakes	Regular intake of solid and liquid water but not sufficient
BIA n°3	March, 09	**PTP n°3**: Competitive Period – Before 1st competition	Classic intakes	Water intakes during training sessions
BIA n°4	April, 09	Before 2nd competition	Classic intakes	Important water intakes during training session and recovery period
BIA n°5	June, 09	Before 3rd competition		
BIA n°6	July, 09	Before 4th competition		
BIA n°7	August, 09	**PTP n°4**: First tapering period		
BIA n°8	August, 09	Before 1st major objective		
BIA n°9	September, 09	After recovery of 1st major objective		
BIA n°10	October, 09	**PTP n°5**: Second tapering period		

2.2. Material and collected data.

The body composition analyzer used for this study is a Z-Métrix®, as shown in figure 1 (BioparHom© Company, Bourget-du-Lac, France). It is a multi-frequency impedancemeter validated by a clinical study (2008-A01373-52). It permits to have a wrist-ankle body measurement. The current injected have a low intensity (77µA). It permits to collect resistances (R) and reactances (X) on all frequencies from 1 kHz to 1000 kHz.

Using a new model derived from Cole-Cole model [7;8], resistances of extracellular compartment (Re) and total body compartment (Rinf) are extrapolated. With undisclosed equations, hydric, tissular and metabolic indicators can be calculated.

Fig.1: Z-Métrix® (BioparHom© Company).

Regarding tissular distribution data, Z-Métrix® calculated in independent way Fat Mass (FM) and Muscle Mass (MMus) [9]. Concerning fluids data, Z-Métrix® calculated in independent way Total body water (TBW), body hydration rate (TBW/W). As regards metabolic data, Z-Métrix® calculated Body Cell Mass (BCM) and Metabolic Activity Indicator (MAI).

The training data are collected every day with a portable GPS & Heart Rate monitor, and Training Load was expressed in Trimps [10].

3. Results & Discussion.

3.1. How knowing tissular distribution with BIA can explain body weight variations?

We can observe body weight and Fat Mass (FM) variations in figure 2. The most important body weight variation is a decrease observed between BIA n°1 and BIA n°2 where he loses 5.4kg (73.9kg to 68.5kg), that correspond to approximately 77g per day.

Like body weight, FM variations have a decrease between BIA n°1 and BIA n°2, where he lost 4.3kg of FM (8.9kg to 4.6kg, or 12% to 6.7%), that correspond to approximately 61g per day.

Then, we can observe an increase around BIA n°6, where he gained 1,7kg (4.6kg to 6.3kg).

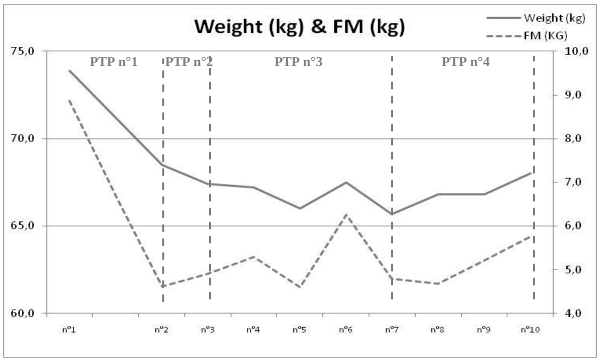


Fig.2: Body weight and Fat Mass variations.

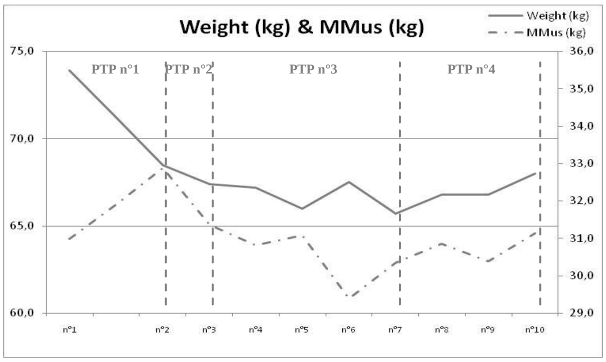


Fig 3 : Body weight and Muscle Mass variations.

In addition to FM, BIA can express, Muscle Mass (MMus), indepedently FM. For this runner, we can observe body weight and Muscle Mass (MMus) variations in figure 4.

We can see there was an increase between BIA n°1 and BIA n°2 (31kg to 32.9kg), that corresponding to approximately 41g per day.

Then, like FM, we can observe a decrease of MMus around BIA n°6, where he lost 1,7kg (31.1kg to 29.4kg).

Between BIA n°1 and n°2, body weight lose can be partly explain by FM lose. These variations are due to his nutritionnal status and his training during this period: decrease of fat intakes, increase of protein intakes, high volume training.

Around BIA n°6, the body weight variation can be explained by a FM gain and a MMus lose. These modification are certainly due to a decrease of strictness in his nutritionnal strategy.

Between BIA n°2 and BIA n°10, except around BIA n°6, we can see this runner reach a certain stability of Body Weight, FM and MMus. He continued his nutritionnal strategy and his training load increase gradually during the season, like shown in figure 6(b).

Thus, we are thinking that BIA method might be use in routine in order to explain body weight variations in elite runner.

3.2. How BIA permit to know and optimize hydration state?

Body Hydration rate variations are shown in Figure 4(a). We can see two clear variations in hydration rate during all the season: between BIA n°1 and n°2 (55.09% to 59%), and between BIA n°7 and n°8 (58% to 62%).

Like showed in Methods, this runner began to modify his hydration strategy after BIA n°3, and we can see there was an effect after BIA n°6, where his hydration rate increase until expected value of 62%.

Therefore, BIA permitted to highlights this runner was in dehydration state, and then, permitted to quantify his progress after turning his hydration strategy.

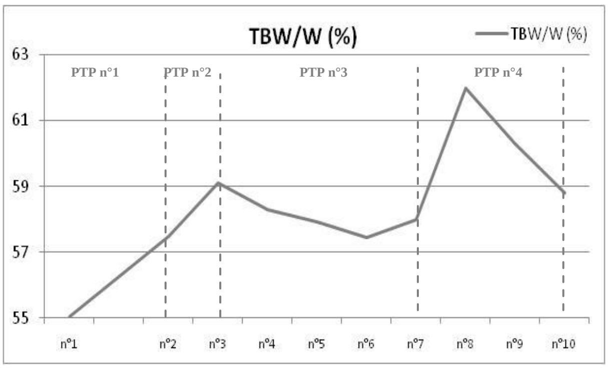
3.3. How BIA metabolic indicators monitoring can express training effects?

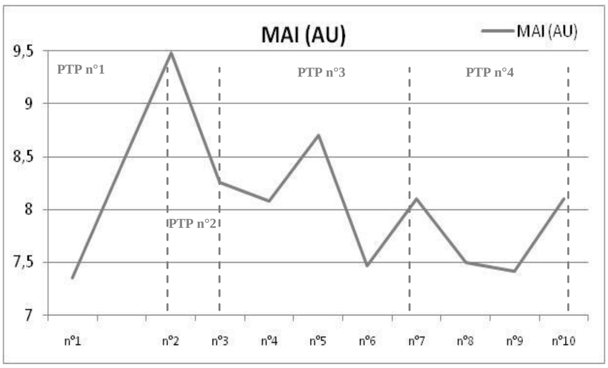
Metabolic Activity Indicator variations are shown in Figure 4(b). A non-pathological value for this indicator is about 7.1±1AU, for a healthy 20-29 years old man. For this runner, his average MAI is about 8.1±0,7AU during the season.

We can observe that this indicator had an increase of 2.1 AU between BIA n°1 and n°2 (7.4 to 9.5). During PPT n°1, he had an increase of training load especially due to an increase of training volume. Thus, we are thinking positive training adaptation may induce and increasing of MAI.

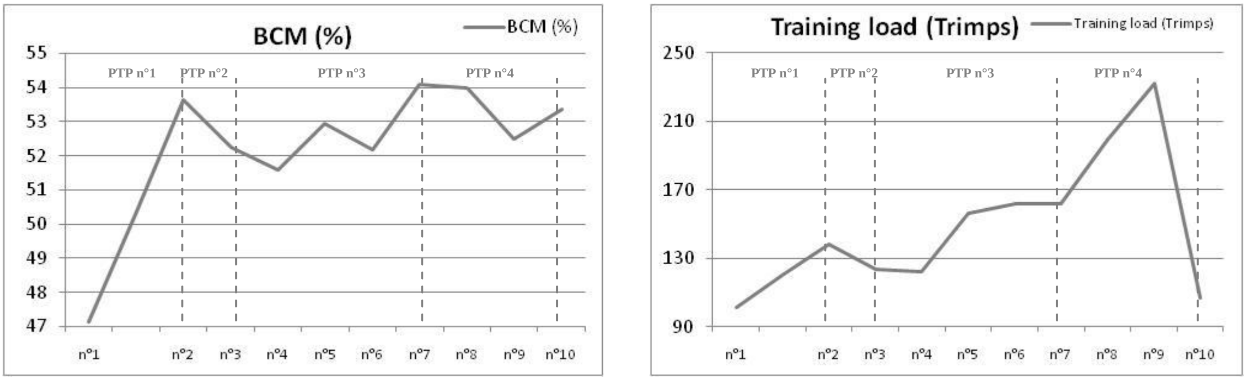
Then, his MAI had the lowest value of the season around BIA n°8 and n°9, so around his major objective. During this competition, he was obliged to stop the race.

Therefore, MAI monitoring might be used in order to follow fatigue state for an elite runner.





(a) <u>Fig 4</u>: Hydration rate (a) and Metabolic Activity Indicator (b) variations. (b)



(a) Fig 5: Body Cell Mass (a) & Training load (b) variations. (b)

Body Cell Mass variations are shown in figure 5(a). We can observe that this indicator follows the same kinetic as MAI. A non-pathological value for this indicator is about 49.4±4.1%. We can observe an increase of 6.5% between BIA n°1 and BIA n°2 (47.1% to 53.6%) and a maximal value for BIA n°7 and n°8 (54%).

According to Varlet [2], this indicator is hardly correlated with performance. For this runner, the increase of BCM between BIA n°1 and n°2 is related to the began of his training and nutritionnal strategy.

After BIA n°3, this indicator had a gradual increase until BIA n°7 and BIA n°8, that might represent his maximal value, certainly because his training reached maximal development state around BIA n°8.

Therefore, BCM might be used in routine in order to estimate maximal development state and to follow performance level of an elite runner.

3.4. How BIA metabolic indicators and training load monitoring can express fitness or fatigue state?

For this runner, around his first major objective (BIA n°8), despite his BCM had a maximal value (54%), he was obliged to stop the race. Moreover, his MAI had a low value (7,5AU).

Nevertheless, around his second objective (BIA n°10), MAI and BCM are both increasing around theirs maximal values (respectively 8,5AU and 53,4%): he won the race.

Our hypothesis is that these two parameters have to be in optimal values; if one of it is too low, the fatigue state is setting up. This hypothesis let us thinking that MAI and BCM may express fatigue state and/or performance state in a longitudinal monitoring for an elite runner. Therefore, BCM and MAI might be used simultaneously in order to express fatigue state or fitness state of an athlete.

Concerning the relationship between training load, like drawn in figure 5(b), and MAI: we can observe an high training load around BIA n°8 (232Trimps) and we have the lowest MAI observed for this period (7,5AU). More, he had a counter-performance, due to physical failure.

An other hypothesis is that a decrease of MAI may be used in order to prevent counter-performance and might be used in order to announce one of the first indicator of over-reaching or overtaining.

4. Conclusion.

This study investigated if BIA and its indicators can be used like a tool for helping technical staff to improve performance, by optimizing training load, specific hydration and specific nutrition.

At first, we attempted to explain body weight variations using tissular distribution variations, in particular Fat Mass (FM) and Muscle Mass (MMus). Our results showed that body composition analysis by BIA permit to explain body weight variations with FM decreasing and MMus increasing. In consequent, BIA might be used in sportive routine in order to follow body composition modifications induced by training.

Then, we attempted to show that BIA allowed to know and monitor the hydration state of an elite runner. Our results showed that this runner was in dehydration state. After optimizing his hydration, BIA permitted to quantify the progress of the hydration rate for this runner. Accordingly, BIA might be used in sportive routine in order to prevent dehydration state and quantify a progress after an hydration strategy.

Besides explaining body weight variations and optimizing hydration state, our results showed that BIA method permit to approach a fatigue state using Metabolic Activity Indicator and to approach a quantifying of performance level using Body Cell Mass.

Moreover, the simultaneous use of Metabolic Activity Indicator (MAI) and training load may allow to express fatigue state or fitness state. Then, the simultaneous use of MAI and Training load let us think that MAI may be used in order to prevent counter-performance and might be used in order to announce one of the first indicator of over-reaching or overtaining.

To conlude, this study let us thinking that BIA method, using a multi-frequency impedancemeter, and independent equations, may be used in sportive routine on elite runner. BIA allowed to explain body weight variations using tissular distribution, to optimize hydration state monitoring hydration rate, and to express a fatigue or fitness state for an elite runner.

In future, the number of subjects should be increased in order to proof these results and other studies have to investigate if metabolic indicators might be used in order to prevent over-reaching or overtraining.

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