Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 00 (2009) 000–000
Procedia Engineering
www.elsevier.com/locate/procedia

8th Conference of the International Sports Engineering Association (ISEA)

Bioimpedance data monitoring in physical preparation: a real interest for performance of elite skiers for Winter Olympic Games 2010

Julien Rebeyrol[a]*, Marie-Valérie Moreno[a], Eva Ribbe[a], Laurent Buttafoghi[b], Olivier Pédron[b], Céline Dechavanne[b] *

[a]*BioparHom, Sport & Research Department, BP238, 73370 Le Bourget du Lac, France*
[b]*FFS, Fédération Française de Ski, 50, rue des Marquisats BP2451, 74000 Annecy, France*

Elsevier use only: Received date here; revised date here; accepted date here

Abstract

The aim of this study is to investigate whether multi-frequency bioimpedance analysis, which is non-invasive, quick and mobile, may be able to optimize training, nutrition and hydration for 9 elite skiers in view to Winter Olympic Games 2010. The principal results of this study is that BIA method may be used in sportive routine on elite skiers in order to estimate Fat Mass, Muscle Mass, Hydration state, Fatigue state and their variations. BIA showed a real interest, for technical and medical staff, because it permitted to optimize and orientate physical training, nutrition and hydration.

"Keywords: Bioimpedance analysis ; Body composition ; 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		

* Julien Rebeyrol. Tel.: +33 951950818 ; +33 626984364.
E-mail address: julien.rebeyrol@bioparhom.com

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 medical and sportive routine.

French elite skiers have a specific preparation to develop their physical qualities in order to be successful for the season. During this preparation, they need to control how body composition is modified by training. They need also a method able to control hydration rates and optimize nutrition. BIA permits to monitor these parameters to be useful in physical training.

Tissular distribution is used to estimate, in particular Weight/Power ratio, in particular. It may be modified with a decrease of Fat Mass (FM), an increase of Muscle Mass (MMus), which may be modified by training or over-reaching [1].

Hydration rate (TBW/W) may be modified by lifestyle or the lack of hydration around exercise, during training session or recovery period. This rate is often used in training because it is considered like a limiting factor of performance [2].

Metabolic Activity Indicator (MAI) can show cellular exchange capacity of subject [3].

The aim of this study is to observe relationship between BIA indicators and medical data collected during medical monitoring of a group of French elite skiers. This study wants to investigate whether using BIA indicators in physical preparation may be able to complete medical data and to adjust training load and nutrition with the aim of 2010 Winter Olympic Games.

2. Methods

2.1. Population.

Our sample is composed by 9 French elite skiers, specialized in alpine skiing slalom. They are all skiing in FIS World CUP 2009 & 2010 and five of them were selected for Vancouver Winter Olympic Games 2010. Their physical characteristics are given in the Table 1.

Table 1: Principal physical characteristics of our 9 French elite skiers.

Skiers data	Mean	±	SD
Age (years)	**27.7**	±	**2.4**
Weight (kg)	**79**	±	**5.6**
Height (cm)	**178.2**	±	**6.8**
Body Mass Index ($kg.m^{-2}$)	**24.9**	±	**1.3**

2.2. Experimental method.

We wanted to observe correlation between data collected by medical staff and data collected by BIA. Our monitoring began in June, 2008 and ended in September, 2009, so 8 medical and BIA measurements were made.

The first five measurements were made between June, 2008 and November, 2008, during the 2008 pre-season physical training period (PTP n°1).

The last 3 measurements were made between June, 2009 and September, 2009 during the 2009 pre-season physical training period (PTP n°2).

2.3. BIA Measurement conditions.

The body composition analyzer permits to have a wrist-ankle left and right measurement. All the measures were made in the morning, before breakfast. During the measure, they were laying down. The measure was repeated three times, after 10 minutes in rest. Height (H), weight (W), age and sex are entered manually in the software.

2.4. Material.

The body composition analyzer used for this study is a Z-Métrix® (BioparHom © Company, France), showed in figure 1. It is a multi-frequency impedancemeter validated by a clinical study (n°2008-A01373-52). The current injected has 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 [4;5], resistances of extracellular compartment (Re) and total body compartment (Rinf) are extrapolated. With Z-Métrix® undisclosed equations, hydric, tissular and metabolic indicators can be calculated on right body and left body.

Fig.1: Z-Métrix® (BioparHom ® France)

2.5. Collected data.

The body composition analyzer Z-Métrix® permitted to collect three kinds of data: tissular distribution data, fluids data and metabolic data. Regarding tissular distribution data, Z-Métrix® calculated in independent way Fat Mass (FM_{BIA}) and Muscle Mass (MMus) [6]. Concerning fluids data, Z-Métrix® calculated in independent way total body water (TBW) and body hydration rate (TBW/W). As regards metabolic data, Z-Métrix® calculated Metabolic Activity Indicator (MAI).

The medical data were collected by the federal physician. Height (H), weight (W), four skinfold, urinary strips (in the morning, before breakfast), biological assessment, data concerning sleep, nutrition, hydration, training data (volume and intensity) and clinical examination were realized. These data permitted to calculate Fat Mass ($FM_{skinfold}$) with Durnin & Womersley 4 skinfold method [7]. Hydration state assessment ($Hyd_{medical}$) was made thanks to urinary strips, which gave urine pH and urine density; and with blood analysis, which gave urea, creatinine and creatinine clearance. Fatigue state (Fatigue) was estimated thanks to biological assessment such as cortisol, testosterone, testosterone/cortisol ratio, CPK and transaminase blood concentrations.

3. Results & Discussion.

3.1. Is there a difference between Fat Mass measured by bioimpedance and by skin-fold method?

During this monitoring, Fat-Mass rates were estimated by skinfold method ($FM_{skinfold}$) and BIA method (FM_{BIA}) on every 8 monitoring sessions. Figure 2 shows the evolutions of FM_{BIA} and $FM_{skinfold}$ during the two PTP (Physical Training Period).

$FM_{skinfold}$ and FM_{BIA} are respectively about 11.1±2.2% and 12.1±1,3% during this monitoring. The average gap between these two methods during the monitoring is about 0.7%.

Our hypothesis is that skinfold method estimates total body FM measuring under-skin Fat Mass, contrary to BIA which expresses directly total body FM.

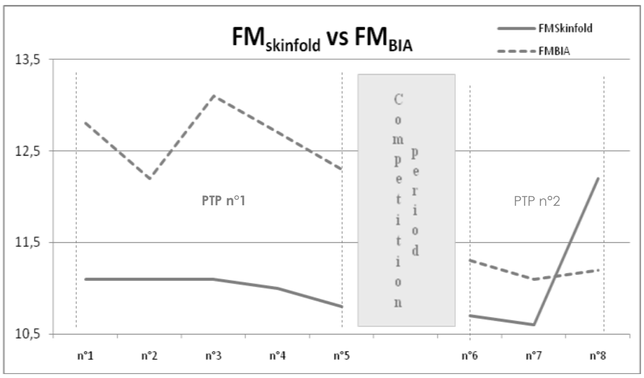

Fig.2: $FM_{skinfold}$ & FM_{BIA} variations.

Table 2 shows mean and standard deviation (Sd) of FM_{BIA} and $FM_{skinfold}$. We can also see there are mainly the same variations of FM, expressed by BIA or skinfold method.

We are thinking that BIA method might be used in routine in order to estimate FM, and to estimate FM variations.

Table 2: Comparison of Fat Mass obtained by BIA and skinfold method during this monitoring.

Monitoring session		$FM_{skinfold}$ (%)				FM_{BIA} (%)			
		Mean	±	Sd	Variations	Mean	±	Sd	Variations
N°1	(June, 2008)	**11.1**	±	2.2		**12.8**	±	1.2	
N° 2	(July, 2008)	**11.1**	±	3.3	=	**12.2**	±	2.5	⇘
N° 3	(August, 2008)	**11.1**	±	2.6	=	**13.3**	±	1.3	⇗
N° 4	(October, 2008)	**11**	±	2.2	⇘	**12.7**	±	1.6	⇘
N° 5	(November, 2008)	**10.8**	±	1.4	⇘	**12.3**	±	0.9	⇘
N° 6	(June, 2009)	**10.7**	±	1.9	⇘	**11.4**	±	1.2	⇘
N° 7	(August, 2009)	**10.5**	±	2.1	⇘	**11.1**	±	1.2	⇘
N° 8	(September, 2009)	**12.2**	±	2.2	⇗	**11.2**	±	± 0.8	⇗

3.2. Does BIA can estimate muscle mass?

In addition to Fat-Mass, BIA method can express a Muscle Mass rate [6].

On figure 3, we can observe variations during the two PTP. Between BIA n°1 and n°2, their training were turning into muscle mass development and we can observe an increase of about 0.6% (about 500g).

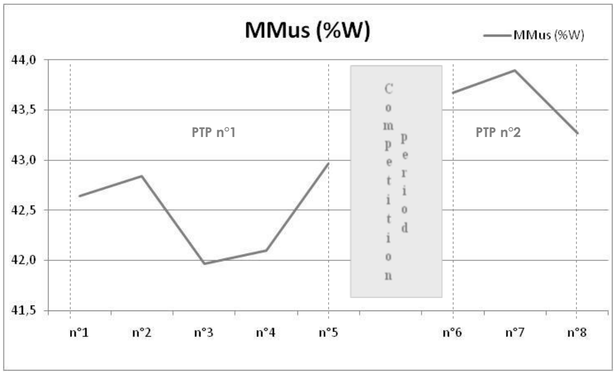

Fig.3: Muscle Mass variations.

Then, between BIA n°2 and n°3, they were in rest and we can observe a MMus lose. Their training load increases, until BIA n°5 and the first competition, and we can observe a strong increase of about 1% (about 800g) of Muscle Mass.

The same variations of MMus are observed between BIA n°6 and n°8 and between BIA n°1 and n°3.

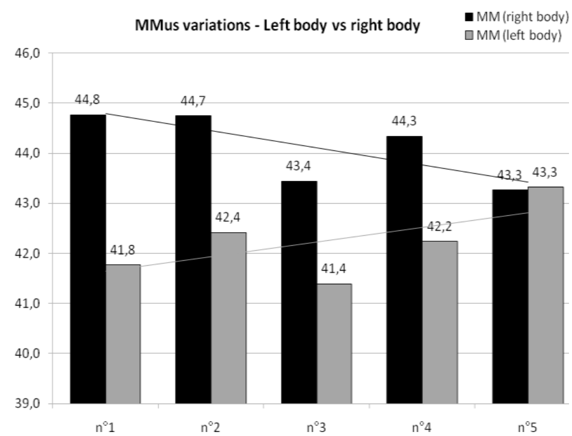

Fig.4: MMus variations on left and right body sides.

Moreover, BIA can express Muscle mass variations on left body side and on right body side. Figure 4 shows these variations.

We can see there were an unbalance between left side and right side on BIA n°1 for MMus. The right side has 3% more than the left side: 41.8% vs 44.8% for the entire group.

After getting this result, the technical staff turns physical training in order to equilibrate left and right sides. On BIA n°5, we can observe a perfect balance with 43.3% on each side for entire group.

More than observe some variations, BIA can orientate physical training, in particular to obtain the balance between the two body sides.

3.3. Is there a difference between hydration rate measured by bioimpedance and estimated by medical method?

BIA can measure with a hard reliability an hydration rate [8] while medical method estimates it using urine pH and density, and creatinine, creatinine clearance and urea blood concentration collected in the morning, before breakfast, so maybe dehydrated by sleeping.

During this monitoring, after a complex analysis, medical data give a binary diagnosis: “hydrated“ or “dehydrated“. On table 3, we can observe medical diagnosis concerning the hydration state ($Hyd_{medical}$) of this group during the study and hydration rate measured by BIA (TBW/W). The medical diagnosis gives the same result during all the study period: the entire group is dehydrated.

Table 3: Average Hydration state.

Skiers data	$Hyd_{medical}$	TBW/W (%)		
		Mean	±	SD
N°1 (June,2008)	**Dehydrated**	**56.1**	±	**2.4**
N°2 (July,2008)	**Dehydrated**	**56.8**	±	**3.2**
N°3 (August,2008)	**Dehydrated**	**55.9**	±	**2.8**
N°4 (October,2008)	**Dehydrated**	**56.2**	±	**2.1**
N°5 (November,2008	**Dehydrated**	**57.1**	±	**3.6**
N°6 (June,2009)	**Dehydrated**	**57.7**	±	**2.3**
N°7 (August,2009)	**Dehydrated**	**58**	±	**0.9**
N°8 (September,2009	**Dehydrated**	**57.8**	±	**2.1**

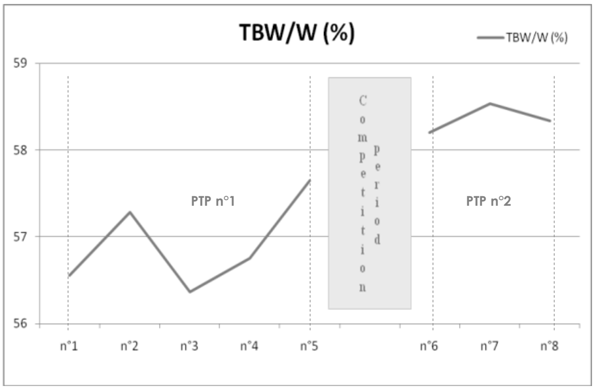

Fig.4: Hydration rate variations.

We can see on figure 4 the evolution of the average TBW/W for this group, knowing healthy rate is about 60%.

Medical and technical staffs attempt to correct the dehydration of the skiers during all the monitoring, optimizing diary hydration, hydration around training sessions and using personal exercise drink for each skier. We can see there were an increase, between BIA n°3 and BIA n°8, of about 2%, approaching 58.5% as shown in table 3. Here, BIA permits them to quantify the progress of hydration rate on each skier.

Therefore, BIA method and medical method gave approximately the same information concerning the hydration state of the group. But BIA permits to have a quantitative idea of the amplitude of dehydration. This information was essential in order to correct their hydration around exercise (training or competition), and medical and technical staff can quantify the progress of hydration rate for the entire group.

3.4. Is there a difference between fatigue approached by bioimpedance and by medical method?

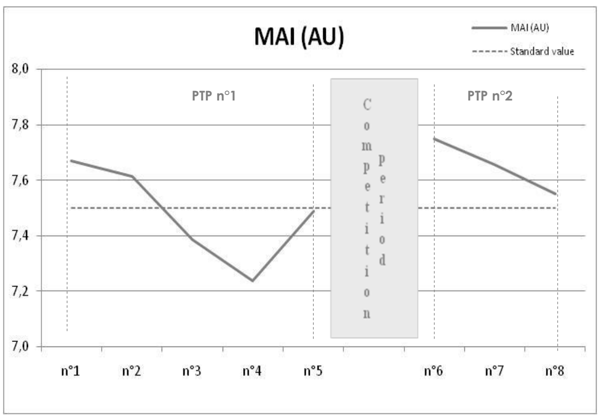

Fig.5 : Metabolic Activity Indicator variations.

Table 4 : Average fatigue state.

Skiers data	Medical estimation	MAI (AU)		
		Mean	±	SD
N°1 (June,2008)	**Not tired**	7.7	±	**0.5**
N°2 (July,2008)	**Not tired**	**7.6**	±	**0.5**
N°3 (August,2008)	**Not tired**	**7.4**	±	**0.6**
N°4 (October,2008)	**Not tired**	**7.2**	±	**0.5**
N°5 (November,2008	**Not tired**	**7.5**	±	**0.9**
N°6 (June,2009)	**Not tired**	**7.8**	±	**0.4**
N°7 (August,2009)	**Not tired**	**7.7**	±	**0.4**
N°8 (September,2009	**Not tired**	**7.6**	±	**0.4**

During this monitoring, fatigue was estimated by medical staff using cortisol, testosterone, testosterone/cortisol ratio, CPK and transaminase blood concentrations. After a complex analysis of these parameters, this method permitted to have a binary diagnosis: “Tired” or “Not tired“. BIA method used Metabolic Activity Indicator (MAI), which traduces cellular exchange capacity. MAI healthy subject value is about 7.5±0,2AU, for 20-29year old men (standard value). MAI may express the fatigue state of skiers, using the hypothesis of implication of MAI in fatigue [3]. The diagnosis of fatigue state given by medical staff for the entire group is noted in table 4 and the variations of MAI are drawn in figure 5, where the standard value is drawn. We can observe that the binary result for fatigue state is the same on each measurement: “Not tired“. MAI also permitted to observe variations in order to orientate training. Between BIA n°1 and BIA n°4, there was a constant decrease of MAI. It can be explained by the high intensity and high volume of a training session. After BIA n°4, one month before the first competition, they began a tapering period (decrease of training volume in order to maintain physical qualities and optimize fatigue state) [9]. During this period, there was an increase of MAI. It can be explained by the positive effect of tapering period realized between BIA n°4 and n°5. Therefore, BIA permits to have an idea of the fatigue state variations. This information was essential in order to adapt training load or more, the real effect of their tapering periods.

Conclusion

This study investigated whether using Bioimpedance Analysis (BIA) indicators in physical preparation may be able to complete medical data and to adjust training load and nutrition with the aim of 2010 Winter Olympic Games.

Concerning tissular distribution, in particular Fat Mass (FM), we compared BIA method and skinfold method [7]. Our results showed that BIA method might be used in routine in order to estimate FM, and its variations. In addition to FM, BIA method is able to estimate Muscle Mass (MMus), its variations and its distribution in each body side. Consequently, BIA can orientate physical training, in particular to obtain a tissular balance between each body sides.

Concerning fluids, BIA method and medical method gave approximately the same information concerning the hydration state of the group. But BIA permits to have a quantitative idea of the amplitude of dehydration. This information was essential in order to correct their hydration around exercise (training or competition). More, medical and technical staff can quantify the progress of hydration rate for the entire group.

Besides tissular distribution and hydration state, our results showed that BIA method might be used in order to estimate fatigue state with quantitative data, which allowed the technical staff to adapt training load, and observe the positive effect of tapering period.

To conclude, this study let us think that BIA method, using a multi-frequency impedancemeter, and independent equations, may be used in sportive and medical routine on elite skiers. BIA permitted to estimate Fat Mass, Muscle Mass, Hydration state, fatigue state and their variations during a preparation of a major objective, such as Winter Olympic Games 2010.

References

[1] Kreider R., Fry A., O'Toole M. L. *Overtraining in sport*, Human Kinetics Publishers;1997.

[2] Costill DL, Wilmore JH. *Physiology of Sport and Exercise*, Eds DeBoeck Université; 2002.

[3] Barbosa-Silva MC, et al. Bioelectrical impedance analysis in clinical practice: a new perspective on its use beyond body composition equations. *Clinical Nutrition metabolic Care* 2005;**8(3**):311-7.

[4] Coles KS, Cole RH. Dispersion and absportion in dielectrics. *Journal of Chemical Review* 1941:209-241.

[5] Moreno MV. Etude de la composition corporelle par impédancemétrie sur des adultes et des enfants sains et pathologiques. Thèse de Doctorat Génie Biomédical, UTC, 2007.

[6] Wang Z, Zhu S, Wang J, Pierson R, Heymsfield SB. Whole-body skeletal muscle mass: development and validation of total-body potassium prediction models. *American Journal of Clinical Nutrition* 2003;**77**:76-82.

[7] Durnin JV, Womersley J. Total body fat, calculated from body density, and its relationship to skinfold thickness in 571 people aged 12-72 years. *Proc Nutr Soc* 1973;**32(1**):45A.

[8] Ellis KJ, Wong WW. Human hydrometry : comparison of multifrequency bioelectrical impedance with ^2H_2O and bromine dilution. Journal of Applied Physiology 1998;**85(3)**:1056-62.

[9] Pradet M. *La préparation physique*, INSEP Publication; 1996.