# CHAPTER 6

# DISCUSSION

In his recent seminal paper, Heymsfield et al. (1) addressed a very interesting and important scientific question: "Is the end of body composition methodology research in sight?". The justification for this question was based on the observation that over the past several decades, the major body compartments at the four relevant levels, atomic, molecular, cellular and tissue-system/organ has been filled with this specific methodology evolution and other similar parallel developments (2). Indeed, as suggested by Heymsfield et al. (1), the classical body composition map is more concerned with measuring the mass or volume of structures that with their 'functions'. The future of the body composition field is envisioned to ideally capture changes in mass, structure/shape and function over time, characterizing physiological and disease processes *in vivo*. This new trend is considered "….not a science-fiction dream, but a finite current goal of many research groups (1)."

Despite this brilliant analysis by one of the most influential scientist in the field of body composition some work in the area of body composition methodology it is still necessary to improve the accuracy of the available methods to assess different markers of body composition, especially, within the scope of longitudinal studies.

Are all of assessment tools in the management of obesity and in the evaluation and efficacy of weight loss programs equally precise? How much more accurate are specific laboratory methods when compared with field methods? Which method would be more convenient to use in the evaluation of a weight loss management? Are the assumptions or the rules used in the methodology of the different most common methods able to evaluate overweight and obese women changes? These are some questions that need to be answered with the advent of new methodological solutions to assess and track body composition changes.

The prevalence of obesity in the world has increased at an alarming rate in the past few decades (3, 4). However the link between obesity and its related co-morbidities and death is the concomitant increase in fat mass observed as body weight increases (5). These health concerns related to excess body fat and altered body composition have been a major focus of research education and clinical efforts. One consequence of excess body fat in aging humans involves changes in the absolute amounts and proportions of lean mass or muscle tissue to body fat, which can influence muscle function and the risk for disability (6). This is also relevant for athletes and coaches, who can also use this information to optimize their nutrition and training programs. Thus, measurement of body fat in humans has become increasingly important in clinical settings, these data are equally important as a way of assessing the efficacy of interventions designed to alter body fat. Accordingly, weight loss programs should not solely focus on decreasing body weight but, in addition, to focus on decreasing fat mass. Consequently, is has arisen the need for accurate assessment tools in the management of obesity and in the evaluation and efficacy of weight loss programs.

As it was referred in the introduction chapter (*Chapter 1*), the human body has been assessed by the methods that have been available. If it is possible to estimate one component of body composition such as fat mass, the body can be described in terms of a 2-compartment model (2-C model) of fat mass and fat-free mass. This was the earliest attempt at describing *in vivo* body composition and it is still the most common model today. Similarly, if one can measure TBW, the body can be described in terms of body water and dry matter. If the water content of fat-free mass is regarded as constant and fat mass is anhydrous, the measurement of TBW can be used to derive fat-free mass and fat mass. Alternatively, the body can be regard as a 3-compartment (3-C model) made up of fat mass, TBW and dry fat-free mass (mainly protein and minerals). If a third

measurement is added, e.g. mineral content (M) or of total body protein (TBP), the body can be considered as a 4-compartment model (4-C model), fat mass, and the constituents of fat-free mass, namely TBW, M and TBP. (The small amounts of carbohydrate and vitamins are ignored for these purposes). All of these *in vivo* measurements rest on certain assumptions.

The assumption of a constant composition of fat-free mass is central to the 2-C model and methods. As more components are measured in 3- and 4-C models and methods, fewer assumptions are required and these are regarded as superior to 2-C methods. Furthermore, in laboratory settings they have an important role in the study of healthy body composition by validating simpler methods. The majority of laboratory methods is expensive or requires competent technical expertise. The most commonly used are the 2-C techniques of densitometry and hydrometry. The most commonly used field techniques are skinfolds or circumferences and bio-impedance analysis, although BMI has been widely used as a measure of total body fatness. The apparent simplicity, speed and cheapness of some of the field techniques have led to their popularity in an unquestional way.

These methods have different levels of accuracy. These distinguish components that are measured, from those where the component of interest is derived by transformation of a measured property of the body on the basis of various biological and technical assumptions. For example, hydrometry allows the calculation of fat-free mass by assuming the water content to be 0.73. Much of the error of estimations arises from calibrations being less than perfect for biological and technical reasons, including error in the criterion method. These methodological issues, the related theoretical background, and the empirical evidence of the accuracy and reliability of several methods were reviewed in *Chapter 1*.

Of relevant significance was the critical analysis of the five levels of the body composition and the new scheme that was proposed to identify the relationships between these levels and the laboratory techniques and field methods are provided in **Table 1.7.** For example, considering that DXA measures specific elements, this method should be included in the atomic level, and not in the molecular level, as previously suggested.

The validity and the accuracy of the most common laboratory and field methods (DXA, BIA and Anthropometry, using a waist circumference formula) for measuring changes in composition across a 16-month intervention program of weight loss using a four-compartment model as reference, was studied in *Chapter 3*. It was observed that, at baseline and after intervention, both Antrform and DXA overestimated fat mass and percent fat mass while BIA-Tanita and BIA-BF300 underestimated fat mass and percent fat mass. Thus, the estimation of fat mass and percent fat mass by Antrform, BIA-Tanita, BIA-BF300 and DXA were not similar to the reference model. It is important to note that before weight loss fat-free mass hydration was significantly higher than the assumed hydration status (76.2% *vs* 73.8%) based on chemical cadavers analysis, which is not observed after intervention (74.4% *vs* 73.8%), as it was theoretically expected (7). These differences can lead to an underestimation of fat-free mass with BIA in the dehydrated state and an overestimation in the overhydrated state (8). These findings may, also, explain the significant increase in the $D_{FFM}$ after weight loss.

In *Chapter 3* it was observed that the mean bias in estimating fat mass and percent fat mass changes by Antrform, BIA-Tanita and BIA-BF300 were not similar when compared to the reference method. As in the cross-sectional data analysis, DXA overestimated fat mass change while Antrform underestimated absolute and percent fat mass changes. Likewise to the findings of Evans et al. (9), the other two single

frequency BIA devices similarly estimated the fat mass changes when compared to the four-compartment model. Conversely, Fogelholm et al (10) found that BIA underestimated the change in fat mass when compared with the four-compartment model. Contrary to expected, fat-free mass hydration increased from 72.9% at baseline to 75.7% after the intervention (only 12 weeks of intervention). Besides this methodological issue, the authors speculate that TBW may not have been detected accurately by BIA due to the expansion of the intracellular water associated with the refeeding weight loss-stabilization period after weight loss, because the BIA method is essentially dependent on the extracellular pool. Additionally, the slopes and intercepts for fat mass and percent fat mass changes with the two BIA methods were not different from 1 and 0, respectively, when the four-compartment model was used as reference. This would indicate a good accuracy for BIA-Tanita while BIA-BF300 presented a wide range of individual differences overestimating in subjects that lost less fat mass and underestimating in subjects that lost more fat mass. These results underscore that this method is not sensitive to track accurately individual changes within a wide range of body composition change. Conversely, DXA overestimated more fat mass loss in subjects that lost more fat mass. This finding agrees with the lower DXA accuracy to estimate in larger fat mass subjects (11). Differences between fat mass changes with the BIA-Tanita and the four-compartment model were not associated with body weight changes. Thus, the estimate changes are not dependent of the amount of body weight loss. Worst results were found for the Antrform method, which is in line with the recognition that it is very difficult for anthropometric methods to accurately estimate body composition changes (12).

In *Chapter 4* it was investigated how changes in body weight and composition (commonly seen in a weight loss program) may result in functional alterations in the

$V_{TG}$, and inadequate fat mass assessment with the Bod Pod. Refsum et al (13) has reported a change in lung function (i.e. increased filling of the lungs, improved dynamic function, reduced ventilation disturbances) following weight loss. Moreover, Wannamethee et al. (13-15), concluded that total body fat and central adiposity measured by waist circumference is inversely associated with lung function in non-obese and obese elderly men after adjusting for confounders such as age and height. Functional changes in the measured $V_{TG}$ may be an important methodological issue that needs to be addressed within the scope of the Bod Pod in general, and weight loss programs specifically. Hence, is the Bod Pod still accurate for the assessment of fat mass change after a change in body composition related to physiological conditions involving a weight loss intervention program? Therefore, the purpose of the study was two-folded: to compare changes between the measured and predicted $V_{TG}$ following a 16-month weight loss intervention program and to understand the effect of confounders (e.g. waist circumference) on the measured $V_{TG}$ in pre-menopausal overweight and obese women.

The findings from this study showed that the $V_{TG}$ was significantly overestimated by ~0.2 L when using the predicted $V_{TG}$ equations vs. measuring the $V_{TG}$. A practical example was done in order to appreciate the impact that the $V_{TG}$ plays on the estimation of percent fat mass and absolute fat mass. The final effect on 90 kg women would have resulted in a final BV change of 0.5 L, when $BV_{raw}$ and SAA remained unchanged (78.7 L and -0.9, respectively) with an observed $V_{TG}$ change of 1.2 L. Impacting the estimation in body composition by 2.6% fat mass units (i.e. 2.3 kg of absolute fat mass). Considering that the mean percent fat mass change in this sample was ~3.5% and the change in the measured $V_{TG}$ was ~0.2 L, it would be plausible to

suggest that some of the loss in fat mass observed might have directly contributed to the change in the $V_{TG}$.

In order to explain the discrepant results between the measured $V_{TG}$ before and after the intervention, we hypothesized that body composition changes observed after the intervention, namely central body fat distribution, would significantly impact $V_{TG}$. Our findings presented a 4.2 cm reduction in the waist circumference. This reduction in the waist circumference and consequently central adiposity contributed significantly to the higher measured $V_{TG}$ values, independently of $VO_2$ max and age. These findings extend the results of previous studies which reported inverse associations between lung function and measurements of central adiposity such as the waist circumference (16-20).

Despite several studies having validated the Bod Pod with hydrostatic weighing, DXA, and multi-compartment models in a wide range of populations (children, elderly, athletes, morbid obesity, paraplegics) with the overall consensus showing good agreement (21-23), there was no unequivocal evidence showing that it is really an accurate assessment tool in the evaluation and efficacy of weight loss programs when compared with DXA as reference. Only two studies have assessed the ability of Bod Pod to track changes in body composition over time in combined sample of men (22 and 10, respectively) and women (34 and 12, respectively) during a short period of weight loss (6 months and 8 weeks, respectively) (24, 25). Therefore, this study was designed to look at the ability of Bod Pod to track changes in percent fat mass, total fat mass and fat-free mass during a 16 month weight loss program relative to DXA in a cohort of females. To our knowledge, this paper is unique due to its research design using a long-term weight loss program with a large and specific sample of overweight and obese women.

The findings of this study indicate that there was a difference between Bod Pod and DXA before and after weight loss for percent fat, fat mass and fat-free mass. Bod Pod percent fat and total fat mass was significantly lower than DXA, while fat-free mass by Bod Pod was significantly higher than DXA's. These findings are in line with those from of Weyers et al (24), and in opposition with the findings of Frisard et al (25). Nevertheless, no bias was indicated by the Bland-Altman analysis, demonstrating the ability of Bod Pod relative to DXA to assess percent fat across a wide range of fatness. As assessed with a paired t-test, percent fat changes were tracked similarly by both techniques because there were no differences between the two means, while fat mass changes were borderline significant ($p=0.049$). Furthermore, a Bland-Altman analysis was completed and no significant bias was observed, thus demonstrating the ability of Bod Pod to measure body fat similarly to DXA across a wide range of fatness.

Throughout the development of this investigation, BIA-Tanita, a field method, confirms its accuracy in tracking changes of fat mass after a longitudinal intervention of weight loss program similarly to laboratory techniques as DXA and Bod Pod, despite being a 2-C model. Thus, this relatively simple, quick, portable and non-invasive field method can be used with accuracy in different settings, including private clinics, wellness centres, and hospitals prior to the tools that fully characterize physiological and disease processes *in vivo*.

The results of this investigation allow us to conclude that some of the methods used nowadays regarding the body composition assessment in the difficult field of tracking changes in mass, structure/shape have a good accuracy level and can be safely used in different contexts by researchers, doctors, physicians, nutritionists, educators, coaches, athletes and others. Nevertheless the considerable technological and

scientifical development for which this thesis also adds, new dynamics models that associate mass and structure/shape to its physiological domain are still necessary. Thus all people related to sports and health in general await a more complete method of assessing body composition changes *in vivo* which, besides tracking changes in mass, structure/shape, will track functions overtime.

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