Effects of procedure, upright equilibrium time, sex and BMI on the precision of body fluid measurements using bioelectrical impedance analysis.

S Thurlow[1*], G Taylor-Covill[2], P Sahota[2] and B Oldroyd[1], K Hind[1]

[1] Bone and Body Composition Research Group, Carnegie School of Sport, Leeds Beckett University, Headingley Campus, Leeds, LS6 3QS, United Kingdom.

[2] Faculty of Health and Social Sciences, Leeds Beckett University, City Campus, LS1 3HE, United Kingdom.

*Correspondence: Shane Thurlow. Fairfax Hall, Headingley Campus, Leeds Beckett University, Leeds, LS6 3QS, United Kingdom. Email: s.thurlow@leedsbeckett.ac.uk

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Abstract

Background/Objectives: Extensive work has addressed the validity of bioimpedance (BIA) measurements and the effect of posture on fluid homeostasis. However, limited research has investigated effects of subject preparation. This study aimed to determine the precision of total body water (TBW) and extracellular water (ECW) measurements using a stand-on multifrequency BIA (MFBIA seca mBCA 514/515), in three pre-test procedures: supine, sitting, and following walking, with specific reference to the influence of sex and BMI.

Subjects/Methods: Fifty three healthy, ambulatory men (n=26, age:32.5±9.4yrs) and women (n=27, age:35.2±10.3yrs) received repeat MFBIA measurements (six measurements from 0 to 15 min). Agreement and precision were evaluated for each condition and time point.

Results: Significant TBW sex differences from supine posture were observed for walking (females) and sitting (males) postures. For BMI ($\leq$ 24.9 kg.m^{-2}) significant TBW differences from supine were observed for both sitting and walking and significant ECW differences from sitting were also observed with both supine and walking. There was no significant effect of sex or BMI ($\geq$ 25.0kg.m^{-2}) on ECW measures. Irrespective of sex or BMI, there was close agreement in TBW and ECW precision over the three protocols.

Conclusions: Practitioners can have confidence in the precision of TBW and ECW measurements within a 15 minute time period and pre-testing conditions (supine, sitting or walking) in healthy subjects, though must be cautious in assessments when pre-test postures change. Further research to examine the impact of pre-testing procedures on stand-on MFBIA BIA measurements, including subjects with fluid disturbance, is warranted.

Key words: BIA; body water; fluid status; subject posture; clinical; equilibrium.

Introduction

The accurate assessment of fluid status in subjects is important for the clinical management of many diseases including renal disease, obesity and cystic fibrosis. Knowledge of total body water (TBW) and its compartments extracellular water (ECW) and intracellular water (ICW) has critical importance in particular for parenteral fluid therapy in acute care and for conditions such as peritoneal dialysis and for clinical decision-making on dialysis dose (1-3). In addition, water retention is a common outcome of response to injury and trauma or critical illness (4). A commonly-used method for the estimation of fluid status is bioelectrical impedance analysis (BIA). This method is particularly suited for use in routine clinical practice given its speed of measurement and low cost in comparison to other available methods.

Single frequency bioelectrical impedance analysers (SFBIA) utilizes an alternating electrical current at 50kHz which passes through TBW, and fat being anhydrous, the measured impedance index (Ht^2/R) at 50kHz is proportional to TBW (5,6). Over the last decade, technological advances have led to the introduction of multi-frequency bioelectrical impedance analysers (MFBIA) and bioimpedance spectroscopy (BIS) with segmental analysis to derive body fluid compartments of the arms, legs and trunk. MFBIA has a small number of frequencies (normally four) over the range 1 kHz to 1 MHz. The use of low and high frequencies enable the estimation of ECW, TBW and by subtraction ICW (Maltron Bioscan 920-25 /Bodystat Quadscan 4000). These analysers utilize frequencies 5, 50, 100, 200 kHz. At low frequency (5 kHz) the current passes predominantly through ECW and the impedance at this frequency is used to predict ECW. The impedance at the higher frequencies is used to predict TBW. BIS uses a larger number of frequencies, 50 to 256, over the frequency range 1 kHz to 1 MHz (Fresenius BCM / ImpediMed SFB7). Mathematical modelling then estimates the theoretical impedance at zero frequency, where passage of the current would be entirely through the ECW space, and at infinite frequency, where the electrical current would pass freely through the complete TBW space, including ICW as well as ECW. This allows estimation of ECW, ICW, and TBW volumes (3,7).

Stand-on BIA devices such as the seca mBCA 514/515 have also been developed. Predictive equations are used to estimate the fluid compartments and these have been validated for fluid status and body composition measurements against gold standard reference ranges in an adult multi-ethnic population (8), and normative adult body composition ranges have recently been published (9). The stand-on device has several reported practical advantages, including permanently incorporated electrodes standardising anatomical positioning, built in weighing scales and reduced total measurement time (~17 seconds per measurement) (8), all potential critical factors in obtaining accurate and precise measurements (10,11).

The effect of body posture on BIA measurements is based on the redistribution of body fluids. A change from standing to supine position produces a fluid shift from arms/legs to the trunk. The trunk only contributes about 5% to the total body impedance this results in an increase in total body impedance. A change from supine to standing will produce the opposite effect. To minimise the effect of body posture changes, the recommended equilibrium time before initiating the BIA measurement in the supine position is approximately 10 min. (12). There have been a number of studies investigating the effect of posture differences on equilibrium time, and comparisons of supine / standing modes on body fluid estimates. (13-18). These results have been used to determine the measurement stabilisation time and the effect of postural change on body fluid compartments. However, there is limited data available on upright equilibrium time and variability of the stand-on BIA position. One recent study monitored fluid shifts, taking 6 measurements over a 30min period in both the supine and standing positions. The authors conclude that 5min is sufficient for TBW measurements in either posture, but ECW stabilization required 30min (19). An earlier study of impedance changes of the total body, arms and legs, measured four times in the standing position over 9 hours, concluded that whole body impedance did not change significantly but arms, legs impedance changed significantly in opposite directions, suggesting that impedance should be measured at scheduled times during the day (20).

In clinical practice, BIA testing is performed with varying subject preparations: following the supine position in bed rest-hospitalisation, sitting by the bed side or in outpatients, or immediately following periods of walking to the outpatient clinic. However, to date, there are no standard protocols for subject preparation prior to BIA testing, which can vary within subject when their condition changes, for example, on discharge from inpatients. Further, during stand on BIA testing, subjects are required to remain in upright equilibrium during testing. To date, the optimal time course of subject equilibrium in the upright position pre-measurement remains unknown. Without this knowledge, there is a risk for reaching erroneous conclusions in practice. This may be particularly the case when serial measurements are relied on for monitoring the progression or recovery of a given condition, or the effects of treatment. It is known that BMI can affect the body composition results from BIA (21,22) therefore the effect of BMI on the results of the study require evaluation.

The aims of this study were:

1) To determine *in-vivo* precision of TBW and ECW measurements in three different pre-test procedures designed to replicate clinical practice: supine (bed rest/hospitalisation), sitting (bed side or outpatients), and following a period of walking (out-patients).

2) To determine the influence of sex and BMI ($\leq$24.9kg.m^{-2} and $\geq$2 5.0kg.m^{-2}) on precision.

3) To substantiate the impact of equilibrium time, up to 15 minutes, on the variance of measurement.

4) Provide from an evidence-base, a proposed standardisation procedure on adult subject preparation and equilibrium time for MFBIA measurements on a seca 514/515 stand-on bioimpedance analyser.

Materials and Methods

Study design and subjects

A controlled, cross-over experimental design was utilised for the study, which was reviewed and approved by the Institution's Research Ethics Committee in accordance to the clauses of the Declaration of Helsinki. All subjects provided their signed informed consent prior to receiving any tests or experimental procedures.

The only inclusion criteria for participation in the study were age over 20 years, being ambulatory and capable of standing continuously for 15 minutes. A health screening questionnaire was administered, which included a self-report of current injury, Exclusion criteria included acute and chronic diseases (hypertension, hypotension, renal and cardiac), metallic or electrical implants and any history of fainting episodes. Volunteers were recruited from academic, non-academic and retired staff from two local Universities. Fifty three subjects, men (n= 26) and women (n= 27) took part, and received each of the three pre-test procedures and 18 MFBIA evaluations in total to initially determine effect of sex on precision. Additional analysis was then performed to study the effect of BMI on precision with subjects grouped using WHO classification into normal BMI $\leq$ 24.9kg.m^{-2} (n=34) and overweight / obese BMI $\geq$25kg.m^{-2} (n=19, 4 were obese). Bio impedance measurements were performed using the MFBIA, at 6 time periods within each experimental condition: 0, 3, 6, 9, 12 and 15 min. Estimates of precision were made from paired values between 0 and 3, 6 and 9, 12 and 15 min.

MFBIA: Seca medical Body Composition Analyzer 514/515.

The seca mBCA 514/515 used in this study, is an eight electrode segmental multi frequency analyser that measures impedance at 19 frequencies ranging from 1 kHz to 1 MHz. It is a 'stand-on' MFBIA device where subjects place their feet on top of the electrodes so that the heel is central to the smaller posterior electrode and the forefoot is central to the larger anterior electrode (Fig. 1). Each side of the handrail has six electrodes, two are chosen dependant on the height of the subject with the angle between arms and the body about 30^{o}. The hands touch the electrodes so that the electrode separator is positioned between the middle and ring finger. Each measurement takes approximately 20 seconds. BIA values obtained at 5 and 50 kHz are used in the predictive equations, and it is recommended that subjects should stand for a minimum of 10 minutes before the initial measurement (8). The RMSE for this device has been reported to be 1.34 kg (TBW) and 0.79 kg (ECW) (8).

Experimental conditions

Subjects were asked to refrain from exercise and alcohol consumption in the 24 hours prior to the testing session. They were also asked to consume 500mL of water the evening before the day of testing, and on the morning of testing. Thereafter, the condition was *ad libitum*. On arrival to the Research Unit, each subject was asked to void their bladder. Subjects were also asked not to consume food from 2 hours prior to testing. Testing started at 15 minutes from arrival, and began with height and weight measurements. No food was consumed once testing had started, and although small amounts of water were permitted, no participants requested this.

Three different procedures, before MFBIA measurements, were designed and implemented to replicate clinical practice: supine (bed rest/hospitalisation), sitting (bedside or outpatients), and following a period of walking (out-patients).

Room temperature was monitored throughout each testing session, and remained constant at 23.6 ±1.6 ^{o}C. The first experimental condition involved the subject assuming a supine position with one pillow under the head for support, for the duration of 15 minutes. This condition was designed to replicate bed rest inpatients preparation. Immediately post 15 minutes, the subject received repeat MFBIA assessments, at 0 and 3min dismounting the MFBIA platform in between each measurement. The subject remained standing and measurements were repeated at 6, 9, 12 and 15 minutes. The second condition involved the subject assuming a sitting position on a generic waiting room chair. This condition was designed to replicate waiting in an Outpatients clinic or for an inpatient at the bedside. MFBIA assessments were then conducted from 0 to 15min. The third condition involved the subject walking continuously for 15 minutes, both outside on tarmac surface and inside the building. Walk speed was self-selected based on each subject's individual walking pace. This condition was designed to replicate walking to an Outpatients clinic. MFBIA assessments were then conducted from 0 to 15min. A heart rate monitor was worn to monitor exertion during the walk.

Physical measurements

For all physical measurements, subjects removed all jewellery and wore light-weight clothing that did not contain buckles or catches. Height was measured to the nearest mm using a free-standing stadiometer (seca, Birmingham, UK), and body weight was measured to the nearest kg using the MFBIA device (seca mBCA 514/515, Hamburg, Germany).

Statistical analysis

Data analysis was computed using Microsoft Excel 2007 and SPSS Version 21.0 (LEAD Technologies Inc©). Prior to analysis, normality and equality of variance was assessed using Kolmogorov-Smirnov test. The study group descriptive data were derived as the mean and standard deviation (SD). Sex specific ANOVA was used to determine if any significant differences in the estimates of TBW and ECW, inter and between measurements modes, were observed in the study. Significant main effects were assessed with paired t-tests using a Bonferroni adjustment, with statistical significance set at $p < 0.05$. The ANOVA analysis was repeated for the BMI subgroups.

In-vivo precision of the seca mBCA 514/515 device was derived from paired measurements for each of the procedures and equilibrium time points. Precision is reported as the root-mean-square standard deviation RMS-SD and %CV.

%CV was derived from the equation: *%CV = (SD/mean value) * 100.*

Results

The study group were heterogeneous in age (range: 21.4 to 59.4 years) and included 27 females and 26 males. Descriptive characteristics of the study group sub-divided by BMI classification into two groups: normal BMI (<25kg.m^{-2}) group and an overweight + obese BMI (>25kg.m^{-2}) group, are given in Table 1.

INSERT --Table 1 Descriptive characteristics of study groups --

Mean (SD) baseline blood pressure and resting heart rates were 110/70 mmHg: 62.9 ± 9.0 bpm, and 122/75 mmHg: 62 ± 12 bpm, in women and men respectively.

In females, the mean (SD) TBW ranged from 31.80 ± 3.93 kg (0:3 min post walking) to 32.07 ± 3.83kg (0:3 min post supine). In males, TBW ranged from 46.53 ± 5.10kg (6:9 min post sitting) to 46.76 ± 5.08kg (12:15 min post supine). For all procedures and equilibrium times, TBW RMS-SD precision ranged from 0.10 to 0.24kg (0.33%CV to 0.74%CV) in females and in males 0.12 to 0.26kg (0.26%CV to 0.55%CV) (Table 2).

Anova indicated a significant effect of posture with supine TBW significantly higher than TBW walking (p=0.03) in females and supine TBW significantly higher than TBW sitting (p=0.003) in males (Fig 2). There was no significant effect of time on the measurements and only a small significant effect of posture x time in females (p=0.02).

INSERT --Table 2 Seca mBCA 514/515 derived TBW precision for study groups over three pre-test postures and varying equilibrium time --

In females ECW ranged from 13.76 ± 1.55 kg (12:15 min post sitting) to 13.85 ± 1.51 kg (6:9 min post supine). With males, ECW ranged from 18.39 ± 2.29kg (0:3 min post walking) to 18.54 ±2.30 kg (12:15 min post supine). ECW RMS-SD precision ranged from 0.04 to 0.12kg (0.31%CV to 0.90%CV) in females and 0.06 to 0.11kg (0.30%CV to 0.61%CV) in males (Table 3).

There were no significant effects of posture, time or interaction of *posture x time* on ECW for both females and males (Fig 3).

INSERT --Table 3 Seca mBCA 514/515 derived ECW precision for study groups over three pre-testing postures and varying equilibrium time

With BMI <$25kg.m^{-2}$, the mean (SD) TBW ranged from 36.86 ± 7.32 kg (0:3 min post walking) to 37.20 ± 7.25kg (0:3 min post supine). With BMI >$25kg.m^{-2}$ TBW ranged from 42.92 ± 9.74kg (0:3 min post sitting) to 43.08 ± 9.80kg (12:15 min post supine) TBW RMS-SD precision ranged from 0.14 to 0.24kg (0.41%CV to 0.58%CV) in BMI <$25kg.m^{-2}$ group and 0.13 to 0.23kg (0.34%CV to 0.51%CV) in the BMI >$25kg.m^{-2}$ group (Table 2).

For BMI <$25kg.m^{-2}$ TBW supine was significantly higher than TBW sitting (p=0.001) and TBW walking (p=0.004) (Fig 2). There was no significant effect of time on measurements but there was a small significant interaction of *posture x time* (p=0.02). There was no significant effects of posture, time or interactions of *posture x time* with TBW for BMI >$25kg.m^{-2}$.

ECW ranged from 15.06 ± 2.39kg (0:3 min post sitting) to 15.15 ± 2.40 kg (6:9 min post supine) in the BMI <$25kg.m^{-2}$ group and 17.86 ±3.30kg (0:3 min post sitting) to 17.99 ±3.38kg (6:9 min post walking) in the BMI > $25kg.m^{-2}$ group. ECW RMS-SD precision ranged from 0.06 to 0.10kg (0.41%CV to 0.67%CV) and in the BMI>$25kg.m^{-2}$ group 0.05 to 0.11kg (0.32%CV to 0.58 %CV) (Table 3). There was a significant effect of posture in the ECW BMI <$25kg.m^{-2}$ group with supine and walking greater than sitting (p=0.003 and 0.05). There were no significant effects of posture, time or *posture x time* in the BMI >$25kg.m^{-2}$ group (Fig 3).

TBW and ECW in the post supine procedure had the highest measured values and significant differences were observed with both the sitting and walking procedures. The only significant differences between sitting and walking procedures occurred with ECW in the BMI<$25kg.m^{-2}$ group (Fig 3). There was no effect of time in any of the study groups. Similar posture and equilibrium time measurements were observed between females and the BMI<25kg.m^{-2} groups: body mass 63.5± 8.9kg and 65.7± 9.0kg respectively and between the males and BMI >25kg.m^{-2} groups: body mass 81.6±13.4kg and 84.4±14.8kg respectively for both TBW and ECW this may be due to the similar body masses. TBW post supine in females and BMI <25kg.m^{-2} tended to reduce with time whilst TBW males and BMI >25kg.m^{-2} remained constant.

There was close agreement between all four groups for the RMS-SD precision estimates of TBW and ECW over the three procedures. The TBW precision range for all groups was 0.10 to 0.26kg (%CV = 0.33 to 0.55) and for ECW the precision range was 0.04 to 0.12kg (%CV = 0.31 to 0.91).

Discussion

BIA measurements of body water are frequently used in clinical practice due to their ease of use, portability, rapid measurement acquisition, and cost-effectiveness. In this study we have determined the *in-vivo* precision of a stand on MFBIA (seca mBCA 514/515) for the measurement of TBW and ECW, following three different preparation conditions, and over various upright equilibrium timings. We have demonstrated excellent reproducibility of measurements using MFBIA, regardless of pre-testing condition (supine, sitting or walking) and with no effect of subject upright equilibrium time on precision.

Fluid shifts based on postural changes have been previously investigated using various combinations of supine, seated or standing with the duration of stay in each posture varying from minutes to hours (13,15,19,20,23–25). Our samples with different prior preparation conditions showed effects on both TBW and ECW measurements. Most notably that supine is significantly higher: in TBW in females (compared to walking): in males (compared to sitting): in the BMI<25kg.m^{-2} group (compared to sitting and walking). For ECW measurements, both the supine and walking presented greater values than sitting in the BMI<25kg.m^{-2} group. The difference in measurements is the result of body water redistribution as a consequence of gravity and changes in contributions to whole body resistance (19). Direct comparison with other results (13,15,19,20,23–25) is limited as none have used the stand on MFBIA with its unique electrode arrangement and similar prior preparation conditions. Though, we emphasise the importance that clinicians should adopt the same prior preparation (posture and time) for assessments and lack of interchangeability and agreement between horizontal and vertical measurements up to 30 minutes (16,19).

The results of our study should be of interest and value to health professionals and clinics utilising MFBIA in practice. It is well established that the overriding benefit of MFBIA is the superior precision of the techniques and therefore ability to detect changes in response to nutrition interventions, disease trajectory or treatments. The strength of this advantage is viewed to overcome the limitations of accuracy when compared to outcomes derived from methods such as isotope dilution (3). Previous studies have reported excellent precision for MFBIA in particular, with 1.2%CV for TBW and 0.2%CV for ECW, exceeding precision of SFBIA (26). However, to date, whether or not pre-testing conditions affect the reliability of such fluid status measurements has been hypothetical. In clinical practice, the preparation of subjects can vary from testing immediately from supine position, from sitting in a waiting room or ward, or following walking to an outpatient's department. Prior to this study it was also unclear whether or not a longer duration in equilibrium would provide more reliable results in terms of MFBIA measurements. We have demonstrated no effect of time in upright equilibrium on the reproducibility of MFBIA body water measurements, with application over durations of 0 to 15 minutes. Our results should provide reassurance to health professionals that the high precision of body water measurements using MFBIA is not adversely affected by varying pre-testing positioning conditions or equilibrium time, and thus application of the technique in different scenarios as they arise will not lead to erroneous conclusions during monitoring.

Following most pre-test conditions our findings show no sex-specific effects on MFBIA body water measurement precision, as reported recently elsewhere (26). It was however noticeable that the device performed somewhat better for total body water and extracellular water precision measurements post sitting in males 0.16kg (%CV = 0.34) and 0.08kg (%CV = 0.41) respectively than in females 0.24kg (%CV= 0.74) and 0.12kg (%CV = 0.90%). Although all precision errors were highly acceptable, in females the precision of the immediate TBW measurements post-sitting was poorer than for subsequent measures taken at 6 and 12 minutes post-sitting, where precision improved 2-fold. The reason for this discrepancy appears due to three outliers in the women group. When the three outliers were removed the mean TBW = 32.4 ± 3.4 kg and RMS-SD = 0.14kg with %CV = 0.42%. However, on re-examination, no reason could be found for removing the data.

Our study group comprised of 53 healthy men and women, ranging widely in age and BMI. Therefore, the high precision values are not a reflection of a homogeneous group. All subjects were hydrated from the outset of the study. These results therefore should not be generalised to all adults undergoing MFBIA measurements in practice. It is possible that precision may vary according to hydration and/or disease status, hence it is recommended that further studies are completed in clinical populations. Never-the-less, our findings provide confidence that environmental variables such as subject positioning and time in upright equilibrium up to 15 minutes, do not impact negatively on precision of body water measurements using MFBIA in adults. Further work is warranted to determine if a greater equilibrium time is required for post supine measurements or if a combination of pre-preparation postures ie moving a subject from a supine position to sitting position prior to measurement resolve**s** the observation that TBW post supine in females and in subjects with a BMI <25kg.m^{-2} tended to reduce with time, whilst TBW in males and subjects with a BMI >25kg.m^{-2} remained constant. In addition, studies on subjects with fluid imbalance are required.

To conclude, caution should be taken in testing subjects under differing preparation procedures. The post supine procedure had the highest measured TBW and ECW values with significant differences observed with both the sitting and walking procedures. There was close agreement for precision estimates for both TBW and ECW between the three procedures. Neither sex nor BMI affected the precision measurements of TBW and ECW, regardless of the pre-test procedures. Therefore, clinicians can have confidence in the precision of TBW and ECW measurements within a 15 minute time period, though must be cautious in assessments when pre-test procedures change.

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Conflict of Interest: SECA provided monetary compensation to subjects for their time participating in the study programme. None of the researchers received direct funding from the company.

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Figure Legends:

Fig 1 Illustration of electrode configuration and patient positioning for the MFBIA Seca mBCA 514/515.

Fig 2 Effect of posture, equilibrium time and gender (A) and BMI (B) on Seca BIA estimates of TBW.

Fig 3 Effect of posture, equilibrium times and gender (A) and BMI (B) on Seca BIA estimates of ECW.

Table 1 Descriptive characteristics of study groups

	Females (n = 27)		**Males(n = 26)**		**BMI <25kg.m^{-2} (Females = 19:Males = 15)**		**BMI >25kg.m^{-2} (Females = 8:Males = 11)**	
	Mean ± sd	**Range**	**Mean ± sd**	**Range**	**Mean ± sd**	**Range**	**Mean ± sd**	**Range**
Age (y)	35.2 ± 10.3	24.9 to 59.4	32.5 ± 9.4	21.4 to 55.3	31.8 ± 8.9	22.8 to 59.4	37.5 ± 10.7	21.4 to 55.3
Height (m)	1.639 ± 0.070	1.480 to 1.750	1.779 ± 0.049	1.701 to 1.904	1.703 ± .089	1.524 to 1.850	1.716 ± 0.060	1.480 to 1.904
Weight (kg)	63.5 ± 8.9	48.9 to 82.5	81.6 ± 13.4	61.7 to 125.7	65.7 ± 9.0	48.9 to 82.5	84.4 ± 14.8	60.4 to 125.7
BMI (kg/m^2)	23.6 ± 3.1	19.7 to 31.3	25.7 ± 3.8	20.2 to 35.6	22.5 ± 1.5	19.7 to 24.95	28.5 ± 3.0	25.2 to 35.6

Mean ± sd

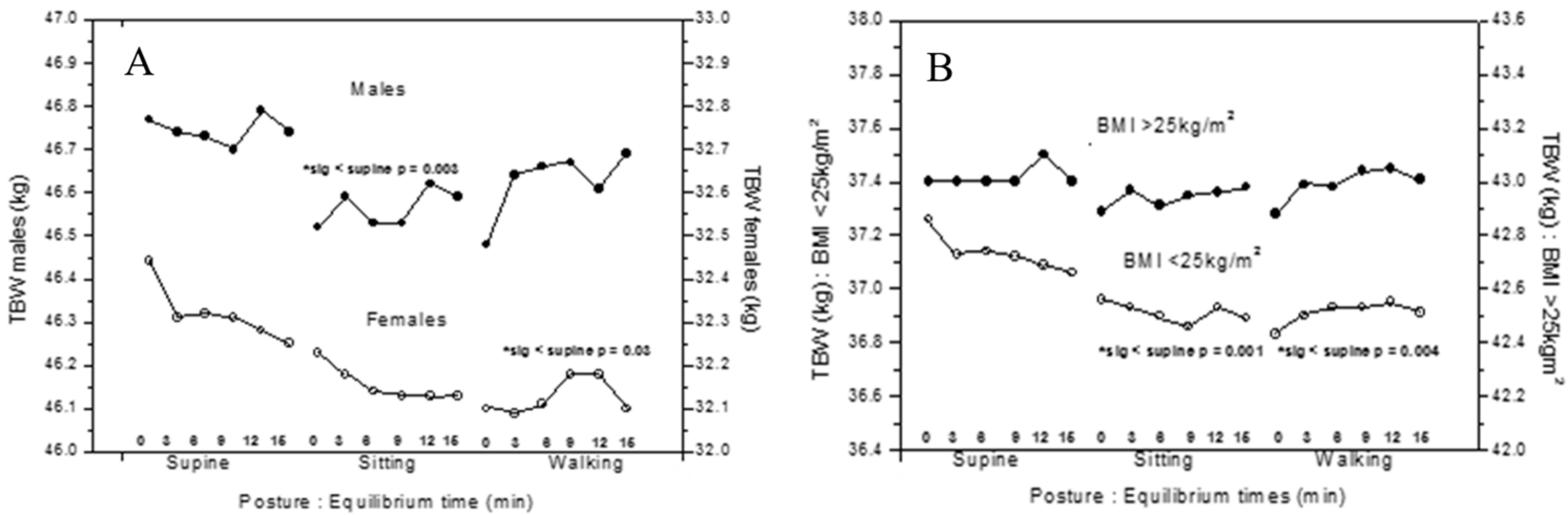

Fig 2 Effect of posture, equilibrium time and gender (A) and BMI (B) on Seca BIA estimates of TBW.

Table 2. Seca mBCA 514/515 derived TBW precision for study groups over three pre-test postures and varying equilibrium time

		Females		Males		BMI<25kg.m^{-2}		BMI>25kg.m^{-2}	
Posture	**Time (min)**	***TBW(kg) (±sd)**	**RMS-SD (kg) (%CV)**	***TBW (kg) (±sd)**	**RMS-SD (kg) (%CV)**	***TBW(kg) (±sd)**	**RMS-SD kg) (%CV)**	***TBW (kg) (±sd)**	**RMS-SD (kg) (%CV)**
Supine	**0-3**	32.07 ±3.83	0.20 (0.60)	46.75 ±4.96	0.19 (0.41)	37.20 ± 7.25	0.21 (0.60)	43.00 ± 9.74	0.16 (0.37)
	6-9	32.02 ±3.84	0.15 (0.47)	46.71 ±5.03	0.12 (0.26)	37.13 ± 7.28	0.14 (0.41)	43.00 ± 9.75	0.13 (0.34)
	12-15	31.97 ±3.83	0.17 (0.52)	46.76 ±5.08	0.13 (0.28)	37.07 ± 7.29	0.14 (0.39)	43.08 ± 9.80	0.16 (0.41)
Sitting	**0-3**	31.89 ±3.96	0.24 (0.74)	46.55 ±5.08	0.16 (0.34)	36.94 ± 7.29	0.22 (0.73)	42.92 ± 9.74	0.16 (0.36)
	6-9	31.84 ±3.97	0.10 (0.33)	46.53 ±5.10	0.18 (0.38)	36.88 ± 7.31	0.14 (0.38)	42.93 ± 9.73	0.15 (0.32)
	12-15	31.84 ±3.96	0.11 (0.35)	46.60 ±5.00	0.24 (0.50)	36.90 ± 7.34	0.17 (0.42)	42.98 ± 9.70	0.20 (0.43)
Walking	**0-3**	31.80 ±3.93	0.18 (0.57)	46.55 ±5.08	0.23 (0.49)	36.86 ± 7.32	0.19 (0.56)	42.93 ± 9.76	0.23 (0.51)
	6-9	31.85 ±3.93	0.15 (0.48)	46.66 ±5.20	0.26 (0.55)	36.94 ± 7.33	0.24 (0.58)	42.99 ± 9.87	0.14 (0.37)
	12-15	31.85 ±3.98	0.20 (0.62)	46.64 ±5.22	0.22 (0.46)	36.91 ± 7.37	0.22 (0.61)	43.03 ± 9.85	0.18 (0.43)

Mean ± sd ***TBW: mean of paired measurements at 0 and 3 min : 6 and 9 min : 12 and 15 min**

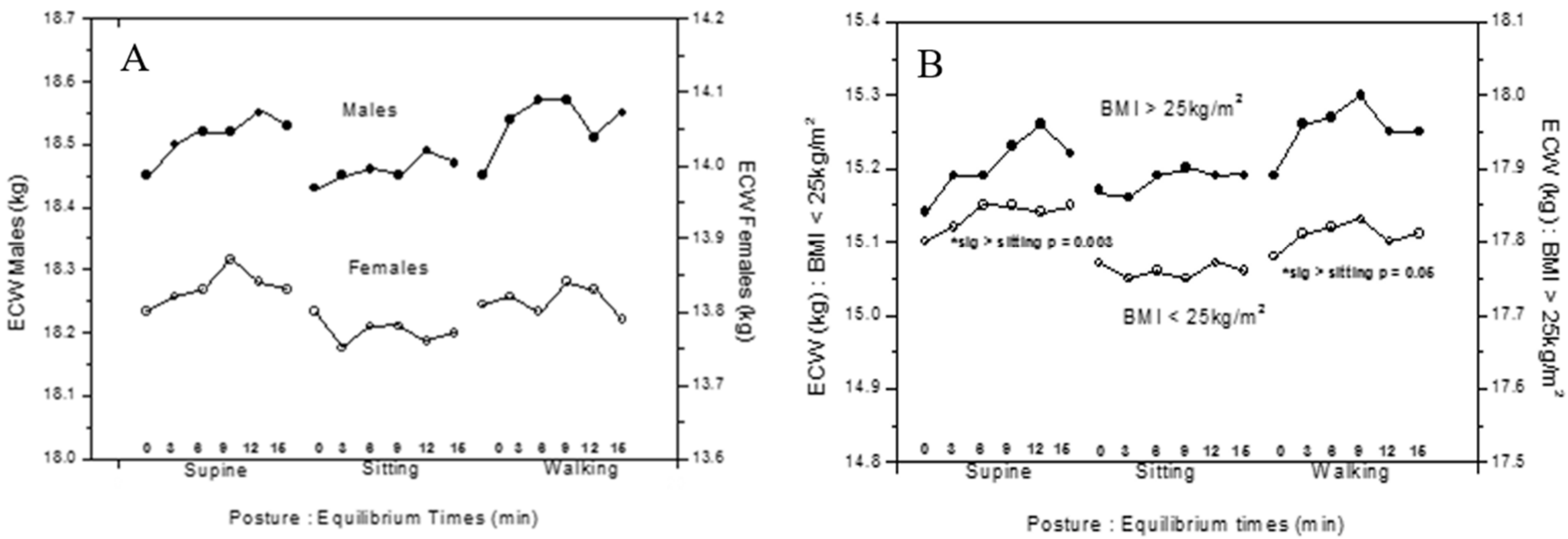

Fig 3 Effect of posture, equilibrium time and gender (A) and BMI (B) on Seca BIA estimates of ECW.

Table 3. Seca mBCA 514/515 derived ECW precision for study groups over three pre-testing postures and varying equilibrium time

		Females		Males		BMI<25kg.m^{-2}		BMI>25kg.m^{-2}	
Posture	**Time (min)**	***ECW (kg) (sd)**	**RMS-SD(kg) (%CV)**	***ECW (kg) (sd)**	**RMS-SD(kg) (%CV)**	***ECW (kg) (sd)**	**RMS-SD(kg) (%CV)**	***ECW (kg) (sd)**	**RMS-SD (kg) (%CV)**
Supine	**0-3**	13.81 ±1.51	0.09 (0.68)	18.47 ±2.27	0.11 (0.57)	15.11 ± 2.38	0.10 (0.64)	17.87 ± 3.29	0.09 (0.51)
	6-9	13.85 ±1.51	0.07 (0.48)	18.52 ±2.28	0.06 (0.32)	15.15 ± 2.40	0.06 (0.41)	17.91 ± 3.31	0.07 (0.40)
	12-15	13.84 ±1.50	0.07 (0.48)	18.54 ±2.30	0.06 (0.30)	15.14 ± 2.41	0.07 (0.43)	17.94 ± 3.32	0.05 (0.32)
Sitting	**0-3**	13.77 ±1.52	0.12 (0.90)	18.44 ±2.31	0.08 (0.41)	15.06 ± 2.39	0.10 (0.67)	17.86 ± 3.30	0.11 (0.67)
	6-9	13.78 ±1.55	0.06 (0.42)	18.46 ±2.33	0.07 (0.39)	15.06 ± 2.41	0.07 (0.46)	17.90 ± 3.31	0.06 (0.27)
	12-15	13.76 ±1.55	0.04 (0.31)	18.48 ±2.27	0.09 (0.51)	15.07 ± 2.42	0.06 (0.38)	17.89 ± 3.29	0.08 (0.44)
Walking	**0-3**	13.82 ±1.53	0.08 (0.58)	18.39 ±2.29	0.11 (0.61)	15.09 ± 2.41	0.09 (0.60)	17.93 ± 3.28	0.11 (0.58)
	6-9	13.82 ±1.54	0.06 (0.46)	18.48 ±2.36	0.11 (0.56)	15.12 ± 2.43	0.10 (0.56)	17.99 ± 3.38	0.06 (0.38)
	12-15	13.81 ±1.56	0.08 (0.56)	18.44 ±2.34	0.11 (0.57)	15.11 ± 2.45	0.10 (0.61)	17.95 ± 3.33	0.09 (0.48)

Mean ± sd ***ECW mean: mean of paired measurements at 0 and 3min: 6 and 9min: 12 and 15 min**