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# Influence of body position on bioelectrical impedance analysis

Investigation of the effects of body position relevant to everyday life on bioelectrical impedance analysis in comparison with clinical application

<https://doi.org/10.1515/cdbme-2025-0219>

**Abstract:** Understanding how body position changes affect bioimpedance is essential for improving wearable technology. This study assessed the influence of posture and time-related changes on whole-body bioimpedance in 12 volunteers, who maintained sitting, standing and supine positions for 15 minutes each. Changes in body position influenced bioimpedance. Transitioning from standing to sitting led to a average bioimpedance decrease of  $-2.97 \pm 1.19\%$ , which reversed when returning to a standing position. Moving to a supine position resulted in an initial increase of in average  $2.55 \pm 1.15\%$ , followed by a further rise to  $4.25 \pm 0.91\%$  over 15 minutes. These results are consistent with previous studies and confirm that deviations from standard clinical positions influence the results of BIA measurements. The study highlights the need to adapt BIA for non-standard positions to optimize and ensure accuracy. Key factors such as hydrostatic pressure on the change in fluid distribution need to be considered in portable BIA applications and future research should incorporate correction models where appropriate.

**Keywords:** bioelectrical impedance analysis, BIA, body position, influence, postural changes

## 1 Introduction

Dilution methods have long been regarded as the gold standard for determining total body water (TBW). These methods are characterised by high precision, but their use is time-consuming and associated with high costs. For this reason, they are not suitable for regular use in clinical and domestic environments [1]. In recent years, bioelectrical impedance analysis (BIA) has established itself as a key method in the

clinical diagnosis and monitoring of body composition. BIA measures the electrical conductivity of the human body and uses the behaviour of alternating current in relation to the TBW and cell membranes to determine body composition using predefined prediction equations. BIA is a cost-effective, reliable and portable alternative that can be used in clinical practice and in portable applications [1–3].

BIA works by passing a small alternating current through the human body, which is modelled as an idealised cylindrical conductor. The resistance to current flow is determined by the measured voltage drop. The bioimpedance consists of two components: the resistance (R) associated with body fluids and the capacitive reactance ( $X_C$ ) associated with cell membranes. This results in a frequency-dependent behaviour because cell membranes act as insulators due to their lipid layer. At low frequencies, current flows only through extracellular water (ECW), while at high frequencies it also passes through cell membranes and intracellular water (ICW) [3].

Resistance correlates with TBW, including ECW and ICW, meaning that changes in the fluid compartments directly affect resistance. Due to the high conductivity of TBW, an increase in TBW decreases resistance, whereas a decrease decreases conductivity and increases resistance. This inverse relationship allows direct assessment of changes in body composition, particularly in TBW, ECW and ICW [4, 5].

BIA is usually performed in a lying position with the extremities abducted. Wearable applications often require a flexible body posture, so that the standardised measurement position must be deviated from. This raises the central question of what effects deviations from the standard clinical method have on the measurement results.

Previous studies have shown that body position has a significant influence on BIA results [2, 6–11]. Not only is the position adopted during the measurement of decisive importance, but the time spent in this position also has a direct influence on the measurement results. The influence of the body position on the measurement results is due to the fact that gravity causes a redistribution of body fluids between the limbs and the torso. The analysed studies show that fluid shifts are caused by hydrostatic pressure changes. When lying down, fluid shifts

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from the extremities to the trunk, whereas it flows back into the legs when standing and sitting. The hydrostatic pressure ensures that fluid in the legs and arms is pressed out of the blood vessels into the surrounding tissue when standing and sitting [2, 7–9, 11]. This effect is particularly significant in the extremities, as the specific resistance of the extremities has a major influence on the total impedance due to their small cross-section and significantly greater length [6]. This leads to measurement errors, which is particularly challenging in the context of continuous wearable measurement systems where the body position is frequently changed. In addition, patients often remain in one body position for a longer period of time, which means that the effect of the redistribution of body fluids must not be neglected here either [1, 2, 6]. Due to the dynamic nature of the measurement results caused by the change in position, standardisation of the results is recommended. The majority of authors recommend carrying out the measurement approximately ten minutes after assuming the supine position [7, 8, 10]. However, the scientific evidence for this time frame is limited, as the measured values of the BIA are still subject to significant change at this time [10].

The aim of this study is to systematically analyse the effects of different body positions and their changes of position on the BIA. The knowledge gained will deepen the understanding of the influence of body position and serve as a basis for the development of correction models for wearable measurement systems.

## 2 Material and Method

The present study examines the influence of body position on BIA by addressing the following central research question: how do BIA measurements change in different body positions (standing, lying, sitting), and what differences arise in the measured values across these positions? In order to answer this question, the study analyses BIA behaviour in various body positions to determine whether deviations from the standardised clinical application affect measurement accuracy.

To answer the questions, a continuous whole-body BIA-measurement is carried out. The measurement is divided into five phases in which the test subjects assume the specified body positions over a defined period. The sequence of body positions was 10 minutes standing (with different arm abduction) and 15 minutes each sitting, standing and finally lying down.

The impedance measurements were performed with a a phase sensitive device (BIA 101 BIVA® PRO AKERN srl, Florence, Italy) working with an alternating current of 250  $\mu$ A at the frequency of 50 kHz. Measurements were performed us-

ing the tetrapolar configuration as described by Lukaski [12]. For the BIA measurement, each participant was in the supine position with a leg opening of 45° compared to the median line of the body and the upper limbs positioned 30° away from the trunk. Very low intrinsic impedance ( $<30 \Omega$ ) disposable electrodes (Biatrodes™ Akern Srl; Florence, Italy) were placed, after cleansing the skin with isopropyl alcohol, on the back of the right hand and two electrodes on the corresponding foot, with a distance of 5 cm between each other [13].

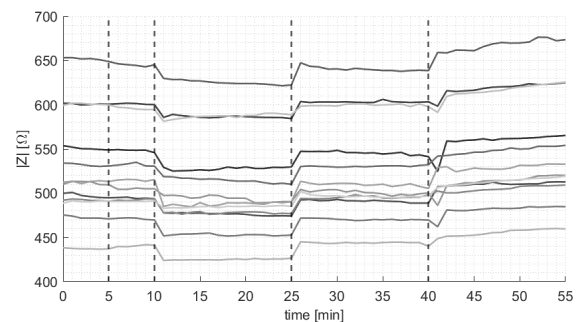
Twelve healthy volunteers aged between 23 and 30 years were selected for this study, with an average age of  $25.33 \pm 2.10$  years. The participants consisted of five males and seven females. The average BMI of the participants was  $23.52 \pm 2.70 \text{ kg/m}^2$ , with an average height of  $1.75 \pm 0.08 \text{ m}$  and an average weight of  $71.69 \pm 7.13 \text{ kg}$ . Before the study, participants were screened for contraindications and instructed to fast for two hours pre-measurement to minimize fluid distribution disturbances [14].

For result evaluation, the focus is on the relative deviation after the phase change alongside raw values. The last measured value before each position change serves as the reference for transition analysis.

- Phase 1-2:  $t_5$  (5 min)
- Phase 2-3:  $t_{10}$  (10 min)
- Phase 3-4:  $t_{25}$  (25 min)
- Phase 4-5:  $t_{40}$  (40 min)

## 3 Results

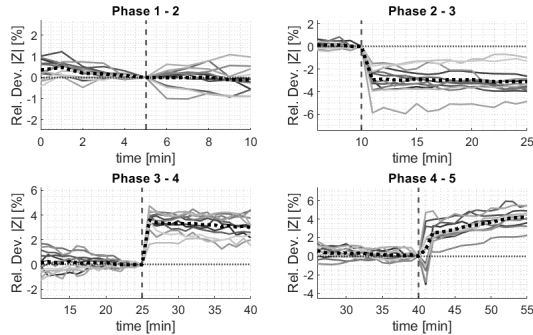
Figure 1 presents the raw data of the bioimpedance measurement. The impedance values are higher in the standing position than in the sitting position. There is a noticeable drop in



**Fig. 1:** Progression of bioimpedance over time with changes in body position. Dashed lines indicate the times of body position changes; grey lines represent measured values.

impedance when moving to the sitting position, which is re-

versible when the subjects return to the standing position. In addition, after lying down, the impedance values show an initial increase, followed by a further rise throughout the entire observation period.



**Fig. 2:** The progression of the relative deviation of bioimpedance over time, focusing on changes in body position between individual measurement phases. Dashed lines indicate the times of body position changes; grey lines represent measured values; the black dashed line denotes the mean.

The investigation of the bioimpedance changes in different body positions shows differences depending on the movement phase (see figure 2):

- Phase 1-2: The bioimpedance remains almost constant with in average minimal fluctuations below 1%.
- Phase 2-3: While bioimpedance remains nearly stable in the standing position, changing to the sitting position leads to a drop of  $-2.97 \pm 1.19\%$ , with individual differences.
- Phase 3-4: The bioimpedance increases by  $3.61 \pm 0.81\%$  when changing to standing, with a high dispersion of individual values.
- Phase 4-5: After an initial increase of approximately  $2.55 \pm 1.15\%$ , the relative bioimpedance change continued to increase, reaching  $4.25 \pm 0.91\%$  compared to the reference value at the end of the measurement period

To summarise, the change in position between the three positions leads to a change in bioimpedance. Depending on the position, the transitions lead to a decrease or increase in the measured values. In the sitting and standing positions, the measured values remain stable on average and only show a slight change over the course of the measurement phase. In contrast, transitioning to the supine position leads to an initial increase in all participants, followed by a continuous rise until the end of the measurement period. The results demonstrate that changes in body position impact BIA measurements. The changes in the BIA measurement values are particularly dy-

namic in the supine position. Accordingly, the measurement is directly influenced by the body position.

## 4 Discussion

The transition from standing to sitting results in a decrease in bioimpedance, with values remaining almost constant during the sitting phase. On returning to the standing position, this decrease is reversible and impedance values return to their initial levels. A slight overall decrease is observed during both phases of standing. However, the most relevant change occurs during the transition to the supine position, where impedance values increase immediately and continue to rise.

Various studies have described similar research approaches for classifying the influence of body position on BIA measurement values. For example, in a comprehensive study with over 200 participants, Rush et al. show that bioimpedance is on average  $12 \Omega$  higher when lying down than when standing [9]. A similar deviation was observed in the present study. Between the change in position from standing to lying down, the bioimpedance increases on average by  $13.41 \Omega$  after two minutes.

Kushner et al. measured a relative deviation in bioimpedance of 3% when transitioning from a standing to a supine position. The difference measured in the present study is 2.55% which is slightly lower than the deviation reported by Kushner et al. In addition, the study by Kushner et al. observed a continuous increase in bioimpedance values of approximately 1–2 percentage points over 10 minutes [6]. The increase observed in the present study is approximately 1.5 percentage points.

Comparison with the literature confirms that the results obtained are in line with previous studies, allowing comparable observations to be made under the measurement conditions used in this study. However, the comparison between the studies is subject to uncertainties, as they often use different study designs. For example, some studies use the bioimpedance spectroscopy (BIS) method instead of the standard BIA measurement at 50 kHz to assess the whole-body impedance across multiple frequencies. The multi-frequency measurement allows a more precise determination of the extracellular resistance and the assessment of the distribution of body fluids. In some studies, the extracellular resistance is therefore calculated directly instead of the bioimpedance at 50 kHz as in the present study. Such methodological differences must be taken into account when assessing and interpreting the results.

The variations in bioimpedance between different body positions indicate that the calculation of body composition in positions deviating from the standard clinical application may

lead to inaccurate volume estimations. Additionally, the measured values in the lying position show a lack of stability.

As explained before, the observed changes can be attributed to fluid shifts in the human body due to changes in hydrostatic pressure. In order to ensure an accurate determination of the body composition in different body positions, correction factors should therefore either be integrated into the underlying calculation formulas or special correction models should be taken into account. Without these adjustments, absolute errors in the range of 2.55% to 3.61% occur between different body positions. Furthermore, it is essential to take into account the temporal dynamics of the fluid distribution due to the influence of hydrostatic pressure during measurement. In this context, there is still a need for research, which requires the development of additional correction models. These models should be evaluated on the basis of a larger sample to ensure their applicability to a wider population. In addition, the use of acceleration sensors could continuously determine the body position during the measurement and thus dynamically apply the appropriate correction model. This would enable reliable, position-independent and continuous measurement of BIA and consequently body composition in wearable systems.

## 5 Conclusion

In summary, the study provides a comprehensive insight into the influence of body position on the BIA measurement. It shows the difference in measurement results in positions deviating from the clinical standard and emphasises that the BIA must not be used without adjustments for other body positions. To ensure precise measurement, essential factors such as hydrostatic pressure on fluid distribution in the human body must be considered. Future research should take these influences into account when developing portable BIA applications and, if necessary, compensate for them with correction models.

### Author Statement

Research funding: The author state no funding involved. Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

## References

- [1] Medrano G, Leonhardt S, Zhang P. Modeling the influence of body position in bioimpedance measurements. 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2007;2007:3934–3937.
- [2] Scharfetter H, Monif M, László Z, Lambauer T, Hutten H, Hinghofer-Szalkay H. Effect of postural changes on the reliability of volume estimations from bioimpedance spectroscopy data. *Kidney international* 1997;51:1078–1087.
- [3] Kyle UG, Bosaeus I, Lorenzo AD de, et al. Bioelectrical impedance analysis—part I: review of principles and methods. *Clinical Nutrition* 2004;23:1226–1243.
- [4] Dittmar M. Reliability and variability of bioimpedance measures in normal adults: effects of age, gender, and body mass. *American journal of physical anthropology* 2003;122:361–370.
- [5] Lorenzo A de, Andreoli A. Segmental bioelectrical impedance analysis. *Current Opinion in Clinical Nutrition and Metabolic Care* 2003;6:551–555.
- [6] Kushner RF, Gudivaka R, Schoeller DA. Clinical characteristics influencing bioelectrical impedance analysis measurements. *The American journal of clinical nutrition* 1996;64:423S–427S.
- [7] Slinde F, Bark A, Jansson J, Rossander-Hulthén L. Bioelectrical impedance variation in healthy subjects during 12 h in the supine position. *Clinical Nutrition* 2003;22:153–157.
- [8] Fenech M, Jaffrin MY, Malmén U. Reversibility of artifacts of fluid volume measurements by bioimpedance caused by position changes during dialysis. *The International journal of artificial organs* 2002;25:217–222.
- [9] Rush EC, Crowley J, Freitas IF, Luke A. Validity of hand-to-foot measurement of bioimpedance: standing compared with lying position. *Obesity (Silver Spring, Md.)* 2006;14:252–257.
- [10] Gibson AL, Beam JR, Alencar MK, Zuhl MN, Mermier CM. Time course of supine and standing shifts in total body, intracellular and extracellular water for a sample of healthy adults. *European journal of clinical nutrition* 2015;69:14–19.
- [11] Fenech M, Jaffrin MY. Extracellular and intracellular volume variations during postural change measured by segmental and wrist-ankle bioimpedance spectroscopy. *IEEE transactions on bio-medical engineering* 2004;51:166–175.
- [12] Lukaski HC, Bolonchuk WW, Hall CB, Siders WA. Validation of tetrapolar bioelectrical impedance method to assess human body composition. *Journal of applied physiology (Bethesda, Md. : 1985)* 1986;60:1327–1332.
- [13] Dunbar CC, Melahrinides E, Michielli DW, Kalinski MI. Effects of small errors in electrode placement on body composition assessment by bioelectrical impedance. *Research quarterly for exercise and sport* 1994;65:291–294.
- [14] Campa F, Mascherini G, Polara G, Chiodo D, Stefani L. Association of Regional Bioelectrical Phase Angle with Physical Performance: a Pilot Study in Elite Rowers. *Muscle Ligaments and Tendons J* 2021;11:449.