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Unsuspecting Baseline Measurement Variations in Commercial Bioelectrical Impedance Analysis-Driven Wellness Machines

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Abstract— **Bioelectrical impedance Analysis (BIA) is a non-invasive diagnostic technique for body compositional health monitoring. Many commercial products are available with closed-off, proprietary algorithms. Inaccessibility to raw data and algorithms masks measurement errors and introduces variability, exacerbated by the lack of universal standards for commercial data comparison. With raw data access, we uncovered the extent of inherent and induced sources of variation in common measurement regimens by experimentally investigating suspected variables and analyzed these baselines under controlled conditions. This work enhances the assessment credibility in packaged commercial BIA machines by elucidating signs of measurement vulnerability and accounting for any significant deviations in raw data that is otherwise masked by automated equation fitting and data manipulation.**

I. Introduction

COVID-19 global pandemic has exemplified the importance of remote human health monitoring. Amongst diverse biomarkers available, body composition has emerged as a highly promising candidate capable of monitoring ailments, athletic performances and beyond. Bioelectrical impedance analysis or BIA is one of the most well-embraced body composition assessment techniques among similar modalities. Decades of research in BIA has resulted in multiple successful commercial systems. Because only processed compositional outcomes from proprietary formulas are available, users are restricted to using the same machine, settings, and protocols. They become incomparable when switching to other BIA systems. Furthermore, inaccessibility to raw data limits them to detect and compensate for inherent and/or unintentionally exerted external interferences. In this report, we aim to discover and experimentally measure subject BIA baselines under typical conditions and identify any inherent sources of deviation and their extent of influence. Through intentionally exerted influences, we determined the significance of resulting baseline changes. We hope to reinforce the assessment accuracy of any BIA systems, by elucidating unsuspected sources of measurement variables.

II. Methods

A commercially available BIA machine from Bodystat Ltd. granted with access to raw data was used. The raw data consists of impedance magnitude (Z), resistance (R), reactance (X), and phase angle (θ) from 50 discrete frequency interrogations. Per factory specifications, a 2-3 ohms of impedance deviation is the expected norm. For baseline deviation under the most common measurement configurations, 3 positions were tested: standing, seated, and supine. Full-body and segmented measurement (right forearm) modes were carried out for each position. Electrode placements were marked and followed that of the factory manual. Measurement stability was evaluated via a *rapid session*: and *a long session*: 3 *rapid* measurements with a rest of 30 minutes. Furthermore, we evaluated human error contribution and resource-driven variabilities that focused on how electrode-skin variations in electrode placement position, location, contact area influence the collected raw data. For induced variations, we examined how bodily movements and positions of limbs influence the measured data. We then check degrees of muscular tension from holding various weights, and attempted hydration status assessment from right forearm.

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III. Discussion & Conclusion

Inherent variables during BIA measurements can often be innocuous and therefore overlooked. Our experimental results are shown in Figure 1. One of the notable results is the displacement of electrode/s, just 1 cm offset can yield a 17% deviation in measured impedance alone and worsens proportionally. Building on this, electrode area reduction, displacement and cable-tugging can all cause deviation well outside of factory-accepted norm. Induced variables are attributed to any intentionally (albeit innocently) introduced sources of deviations to the measurements such as stomping of feet which drive deviation 6% beyond limit. Furthermore, arm positions that impose muscular strain such as over the head positions also produce unacceptable results. Hence, subject comfort is important throughput measurements, as evidenced by our muscular exertion experiment which yielded deviations >5% above limit regardless of intensity. Hydration is a challenging biomarker for BIA. Our initial study looked the scale of baseline deviation from hourly and daily hydration showed that even in controlled interval of liquid consumption, a baseline drift of up to %10 can result across all frequency ranges. As a conclusion, we heeded caution against binding trust to absolute assessment outcomes and encourages joint analysis of raw and processed data, maintain measurement consistency, and being mindful of unsuspecting influences.

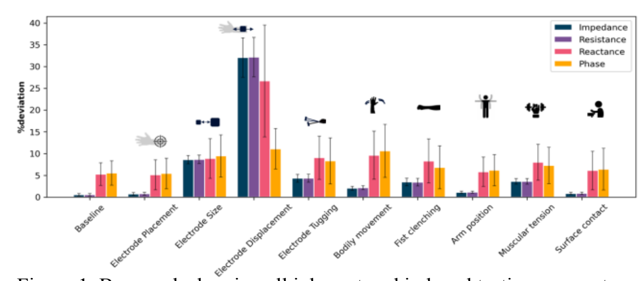

Figure 1. Bar graph showing all inherent and induced testing parameters in the determination of their influence on the measurement baseline.