Perceptions of Body Composition Measurement Instruments: A Pilot Study

Original Research

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Abstract

Introduction: The purpose of this study was to explore collegiate student-athletes' perceptions of undergoing three common body composition assessments: bioelectrical impedance (BIA; Tanita), digital anthropometry (DA; Fit3D), and hydrostatic weighing (HW).

Methods: Twenty male (n=8) and female (n=12) NCAA Division I collegiate athletes (age: 19.6 ± 1.6 yrs.) underwent three body composition assessments in the following order: BIA, followed by DA, and HW. Following the three body composition assessments, participants completed questionnaires regarding their demographic and perceptions towards the various body composition assessments. Data was analyzed for themes using a phenomenological qualitative design.

Results: Ten (50%) of the participants selected the BIA as their preferred method while 8 (40%) chose HW. Only 2 (10%) participants selected DA. Four themes emerged from the qualitative data analysis. Theme 1 - Ease of use and timely measurements; Theme 2 - Accuracy is important; Theme 3 - Body composition instruments are fun to use; Theme 4 - Sense of curiosity and novelty. Participants reported a positive experience undergoing these three body composition assessments.

Conclusions: The emergent themes revealed participants are genuinely concerned with their data/scores while placing importance on accuracy and ease of use. Study results show the importance of considering participant experiences in body composition measurement protocols.

Key Words: body analysis, fat-free measurement, qualitative analysis

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Introduction

Body composition is arguably one of the most important measures of physical fitness and health. Simply put, body composition is the measurement of fat-mass (FM) and fat-free mass (FFM). Fat-free mass includes bones, muscles, water, and organs. Healthy body composition affords individuals a better quality of life, longevity, improved metabolic function, and overall enhancement of physical function. Increased fat-mass, which may be measured using a variety of body composition instruments, leads to increased risks of cardiovascular disease, type 2 diabetes, and several types of cancers.[1] Given its importance, measuring body composition is a valuable tool for assessing and tracking individuals' overall health.

The general population is quite familiar with fitness technology. The top ranked fitness trend for 2023 was wearable technology and it has held the number one position since 2016 with the exception in 2018 (rank #3) and 2021 (rank #2).[2] Nearly one in three Americans use some sort of wearable device (bands, watches, rings, etc.) to track their fitness and wellness.[3] Further, American consumers are willing to spend hundreds of dollars on these wearable devices. The Apple Watch is the most popular brand among US consumers with a 56% market share; Fitbit trackers are second with a 23% market share.[4] As a point of reference, the price of an Apple Watch Series 10 in 2025 is $399.[5] Clearly US consumers have a vested interest in assessing their fitness levels.

Not only are fitness tracking and measurements popular with the general consumer, but in research settings, investigators have been assessing fitness levels for decades using a variety of instruments. These include Dual-energy x-ray absorptiometry (DXA), the BOD POD, skinfold measures as well as bioelectrical impedance (BIA), digital anthropometry (DA), computed tomography (CT), magnetic resonance imaging (MRI), and hydrostatic weighing (HW). As previous research has determined,[6,7] many of these measurement tools have pros (accuracy, easy and inexpensive) and cons (inconvenient, expensive, impractical, state regulations on use). For example, the technologically advanced Dual-Energy X-ray Absorptiometry (DXA) is considered the gold standard in body composition assessment. New models of these machines range in price from $45,000-$80,000.[8] DXA whole-body scanning devices are quite large as well requiring an 80 square foot space for operation. Two additional instruments which may be used for body composition testing are computed tomography (CT) and magnetic resonance imaging (MRI). These are considered computed tomography machines range in price from $80,000 to $300,000 with most MRI devices starting at $500,000 for premium models.[9]

Advancements in technology, which is no doubt expected to increase even more rapidly with the expansion of artificial intelligence (AI), has resulted in researchers exploring the accuracy, validity, and reliability of body composition measurement tools.[10,11] Researchers have sought to determine which method provides the most accurate information for researchers, clinicians, and patients. However, there is a noticeable gap in the literature regarding user (participant) perceptions and experiences with these measurement protocols. Elements such as comfort, convenience, and even psychological impact could help investigators determine which measurement protocol is most appropriate for a given population, keeping in mind that not all laboratories have access to all measurement tools. This is of utmost importance considering voluntary participation in research studies is required regardless of the research setting, from fitness centers and wellness programs to large university-based projects. Therefore, the purpose of this pilot study was to explore collegiate student-athletes' perceptions of three commonly used body composition assessments: BIA, DA, HW.

Theories of hedonic motivation help to explain and predict physical activity behaviors. Hedonic motivation theories purport individuals are more inclined to participate in behaviors previously associated with pleasure and will strongly dislike engaging in behaviors previously viewed as unpleasant.[12] Therefore, a better understanding of participants' preferences and experiences may allow researchers to incorporate more suitable body composition measurements to enhance program adherence and satisfaction.

Methods

Participants

A total of 20 participants (8 male, 12 female) participated in the study. Participants were recruited using convenience sampling at a relatively large university in the southeast (student enrollment approximately 14,000), including undergraduate students and student-athletes. Student-athletes were members of the track, soccer, or volleyball teams. The mean age of the participants was 19.6 ± 1.6 years. The study was approved by the university's institutional review board (IRB) and data collection occurred in fall, 2023 and informed consent was collected from each participant.

Protocol

As previously noted, participants body composition was assessed using BIA, DA, and HW. The BIA measure was taken using a calibrated digital scale (Tanita Corp. TBF-400, Arlington Heights, IL). A whole-body 3DPS was used to measure body composition via DA (Fit3D Proscanner©, Fit 3D Inc.). The last instrument that was used, measuring body composition via HW was a custom fashioned hydrostatic device incorporating a large tank filled with water. Water temperature ranged from 88 degrees Fahrenheit to 94 degrees Fahrenheit.

Each participant first completed the BIA, followed by the DA, and lastly, HW. Immediately after the three tests were completed, participants completed a qualitative questionnaire before exiting the lab. Two researchers were involved in the study administration. A series of open-ended survey questions were presented with responses collected electronically via Qualtrics.

The researchers conducted all three measurements in approximately 15 minutes with the Qualtrics survey averaging 10 minutes in duration per participant. One of the researchers remained in the room as the participants completed the survey on a laptop to ensure there were no questions or technical difficulties. Participants were presented with their body composition assessment results immediately following each test.

Qualtrics Survey Instrument

After completing basic demographic questions, participants responded to the following questions immediately after completing all three body composition assessments:

1. Tell us about your experience completing the electrical impedance body assessment. This is the first test you completed. Be detailed and specific in your response.
2. Tell us about your experience completing the Fit 3D fitness assessment.
3. Tell us about your experience completing the hydrostatic weighing (underwater weighing) assessment.
4. Rank the assessment measures, based upon your level of comfort completing each assessment (1 most comfortable, 3 least comfortable).
5. Explain your reasons/rationale for your first choice above.
6. Explain your reasons/rationale for your second choice above.
7. Explain your reasons/rationale for your third choice above.
8. Tell us about the test environment for the electrical impedance body assessment (i.e. protocol (clothing, etc.) room temperature, device placement, ease of device use and timeliness of results, etc.).
9. Tell us about the test environment for the Fit 3D Test (i.e. protocol - clothing, etc.), room temperature, device placement, ease of device use and timeliness of results, etc.).
10. Tell us about the test environment for hydrostatic weighing (i.e. protocol - clothing, etc.), room temperature, device placement, ease of device use and timeliness of results, etc.).
11. Have you ever completed body composition measures before? If so, please list which ones you have completed.

Selected Body Composition Measurement Methods

This study utilized bioelectrical impedance (BIA; Tanita), digital anthropometry (DA; Fit3D), and hydrostatic weighing (HW) to assess body composition. As previously mentioned, there is a variety of body composition measurement methods. The three devices were selected for the pilot study as they were readily available to the researchers and they are generally accepted, valid, and reliable body composition measurement instruments.

Bioelectrical Impedance (BIA) Devices

Bioelectrical impedance devices measure the body's resistance of a harmless, painless electrical current which then estimates FM and FFM. Lean tissue (muscle) consists of 73% water and is therefore a good conductor of electricity while FM, which lacks water, is a poor conductor.[6] These devices are quite popular choices as they are easily accessible, portable, and reasonably priced. They are, of course, not without drawbacks. The validity and reliability of BIA instruments do vary. Studies indicate BIA devices using single-frequency and multi-frequency may be used for whole-body and segmental body composition with large sample sizes.[13,14] When compared to DXA devices, BIA devices show the largest differences. Inaccuracy increases to a greater degree with higher BMI.[15,16] Accuracy is impacted by users' hydration levels (both under and over hydration), issues such as lower limb swelling, and whether or not a reading was taken when users were in a fasted state.[1]

From the user perspective, BIA devices are simple to use. Handled or hand-to-hand devices provide a body composition reading based on arm and upper trunk bioimpedance. These devices are portable and convenient. Another type of BIA device commonly used in research settings are scales. Users stand barefoot on top of a scale, often while simultaneously holding two handles, and a reading is taken. Direct segmental multi-frequency BIA is considered the most advanced BIA device,[17] where the body is divided into as many as five segments and a reading is taken for each segment.

Digital Anthropometry (DA) Devices

Digital anthropometry devices are non-invasive and optical based. These instruments use 3D imaging, without radiation, which provides a realistic image for users and researchers to study. Since their inception in 1987,[18] the devices have become more advanced, affordable, accurate, and practical. Regarding accuracy, Mocini et al.[18] conducted a systematic review of 28 studies to provide an overview of the current status of DA technology. The researchers reported that the reliability and accuracy of DA was high in most studies. DA's measurements were most useful in the assessment of patients with obesity but there was some variability depending on the type of technology used. Other investigations have shown similar results. Ng et al.[19] for example, found 3D scanners provided accurate body composition and body image/shape but noted software updates were necessary to increase the accuracy.

User-friendliness with DA devices is notable. The operational procedures are fast and simple with results provided immediately. A basic three-step process of data acquisition, processing, and anatomical measurements is used in DA, regardless of the device.[20] Subjects wear minimal clothing and step onto the DA scanning device. Using light scanners, a three-dimensional image is captured in a matter of seconds providing an avatar of the subject. Metrics including body circumference, posture analysis, and body composition are instantly produced.

Hydrostatic Weighing (HW) Protocols

Hydrostatic weighing protocols were once considered the gold standard of body composition measurements. Fat mass and fat-free mass are measured based on Archimedes principle which states, "the upward buoyant force exerted on a body immersed in a fluid is equal to the weight of the fluid that the body displaces."[21(p35)] Applying this principle to body composition measurement, since the weight of a body is less in water than on land, the difference in weight provides an estimate of body volume. Muscle and bone are denser than water whereas fat tissue is less dense comparatively.

There are, of course, cons associated with HW protocols, despite the fact they have for decades been considered valid and accurate.[1] For HW research participants, this method is quite burdensome. Participants are required to sit in a large tank filled with water. They are lowered into the tank sitting on a chair and are totally submerged and exhale completely. Typically, participants hold their breath for approximately 10 to 15 seconds while a measure is taken. Often, several readings are recorded for better accuracy. Patients may struggle with this protocol as they may fear being underwater for a period of time.[1] Compared to other body composition protocols, this method does require more time commitment.

This qualitative pilot study used a phenomenological approach. Creswell[22] defined phenomenology as "a research strategy of inquiry in which the researcher identifies the essence of human experiences about a phenomenon as described by participants" [p13.] Further, Patton[23] describes phenomenology as being concerned with individuals' lived experiences. As such, a qualitative perspective was employed to explore the participants' experiences using various body composition measures.

Phenomenological Approach

This study employed a primarily qualitative, phenomenological design, supplemented by descriptive quantitative summaries of participant preference rankings, for context only. Using a phenomenological approach to explore participants' reactions regarding physical activity and fitness measurement, while not as common as quantitative investigations, still has merit. Kim and Lee's[24] study is one such example. The researchers explored the phenomenological meanings of assessment in Physical Education (PE). Specifically, primary teachers' lived experiences of both being assessed as PE students in the past and assessing primary PE teachers in the present were explored. The qualitative analysis revealed participants' past experiences with assessment. One theme, for example, was "trembling body." Participants recalled being anxious and nervous as they were undergoing fitness assessments at a young age. Another theme was a sense that "big brother is watching me," meaning the participants felt as if they were under constant surveillance during the assessment protocol.

Similarly, Pridgeon and Grogan[25] employed a phenomenological approach to investigate males' and females' experiences of maintaining and dropping out of a gym-based exercise program. Rather than simply using a quantitative approach, akin to a program evaluation survey, the 14 participants participated in semi-structured interviews. The data analysis revealed exercise adherence factors and exercise dropout factors. Again, such in-depth, nuanced analysis is difficult to obtain with closed-ended questions often found in quantitative methodologies. To date, there are no published studies, qualitative, quantitative, or mixed methods, focusing on participants' experiences with various body composition measurement protocols. The current study seeks to fill this gap in literature.

Data Analysis

Using Nvivo 14 Qualitative Software the data was analyzed using a phenomenological qualitative design to explore the participants' experiences using various body composition measures. As noted by Rossman and Rallis,[26] coding is the process of formally categorizing data and thematic analysis. Researchers independently assigned codes to the qualitative survey data and noted similarities within the data. Following Denzin[27] and Patton's[23] conceptualization of analyst triangulation, the two sole researchers coded, analyzed, and interpreted the data independently. Those analytics were then combined and discussed as means of identifying multiple ways to see/interpret the data. Findings and themes

were identified as the final step of data analysis. Any disagreements during initial coding were discussed by the researchers until consensus was reached.

Results

Ten (50%) of the participants selected the BIA as their preferred method while 8 (40%) chose HW. Lastly, only 2 (10%) participants selected DA. The following themes emerged from the data analysis: ease of use and timely measurements, accuracy is important, body composition instruments are fun to use, and sense of curiosity and novelty.

Theme 1 – Ease of Use and Timely Measurements When asked to provide feedback on their experience with each of the body composition instruments, participants responded they were pleased with both the speed of each test and the ease of use. The majority of participants indicated the bioelectrical impedance for example was "quick and easy," followed by the Fit3D, and lastly, hydrostatic weighing. Even though the hydrostatic weighing was not the most preferred method, participants still responded positively overall. For example, one participant wrote, "This was my last choice just because it was the most out of the norm. It was, personally, my favorite test, however, the tasks that needed to be completed were more extreme than the others."

Theme 2 – Accuracy is Important Several of the study participants referenced "accuracy" explicitly with one participant noting the following regarding hydrostatic weighing: "I know it has the best and most accurate results out of all three so I was happy to give this one a try too." An inherent sense of eagerness was evident as participants mentioned they were eager to see the results of all three measures. It is important to note that participants' references to "accuracy" were their subjective perceptions not validated measurement accuracy. Participant beliefs about accuracy may have been shaped by prior knowledge and/or experiences with the instruments.

Theme 3 - Body Composition Instruments are Fun to Use Nearly all of the participants indicated they enjoyed at least one of the instruments and/or provided a general statement of positivity regarding the study as a whole. Regarding the Fit3D, one participant wrote "it was like a ride at Disney," while another wrote, "it was fun and fast." Again, even though the majority of participants did not rank the hydrostatic weighing as the most comfortable, two mentioned the tank was "cool" with one participant going as far as stating she felt like she was "at the spa."

Theme 4 - Sense of Curiosity and Novelty An interesting theme that emerged was participants' level of curiosity. Some were interested in simply obtaining results while others were interested in the methodology associated with the instruments. A female participant noted: "It was an interesting experience and I would like to know more about how the fat mass can be calculated in the water. I am curious to see the results." Similarly, on hydrostatic weighing another wrote, "This is my first time completing this test and it was quicker than I thought it would be. I am very curious about the results."

Discussion

Key findings from the current study extend the literature on body composition from a new perspective – that of the participant. Results indicate an overall positive experience from the participants which is extremely important for health and fitness practitioners, researchers, and health care providers. Bioelectrical impedance was most preferred (50%), followed by HW (40%) and DA (10%). Considering the portability, convenience, and general accuracy of most BIA devices, this is a promising finding of the current study. Likewise, those researchers who currently have access to HW devices may be encouraged to continue to use them in their research protocols. Participants seem genuinely interested in the results of the HW and seemingly do not mind the extra effort to execute the assessment. Lastly, although the DA (Fit3D) was the least preferred method, the participants did not report any negative comments regarding the device. With Fit3D scanners priced around $10,000,[28] researchers operating with a limited budget may be able to pursue other more cost-effective avenues to assess body composition for their participants considering it is a not a top choice.

Theme 1, ease of use and timely measurements, aligns with the aforementioned discussion regarding consumer technology preferences. Perhaps it is no surprise that participants noted their pleasure with the instant results of the three body composition instruments. Most popular fitness wearables provide instant health data as well so participants may be accustomed to, and expect, these timely results. Regarding theme 2, the importance of accuracy, participants valued accuracy even at the expense of comfort. This was evidenced in the feedback with the HW protocol. Theme 3 was concerned with the "fun" factor. With as much as 86% of all clinical studies in the US are unable to recruit the required number of participants efficiently,[29] enjoyment might influence participants' adherence to testing protocols in both clinical or research based settings. Lastly in Theme 4, a sense of curiosity and novelty may likewise be leverage to enhance program/study adherence.

While the four themes derived from the current analysis represent the perspective of participants in the study, similar themes could potentially apply to those conducting the assessments. To reiterate, the four themes that emerged from the pilot study are: ease of use/timely measurements, importance of accuracy, fun experience, and curiosity/novelty. Health and fitness researchers certainly are concerned with easy-to-obtain and timely measurements.[30] This is an asset for any research study. Further, when participants truthfully enjoy the research experience, they could be more likely to agree to additional research opportunities. This may also provide a sense of intrinsic motivation for the researchers, simply knowing their participants are enjoying the process. Lastly, considering the participants felt a sense of curiosity and novelty, this too may increase the likelihood of study adherence and repeated participation.

In the extant literature there are no studies which focus on body composition assessment protocols from the participant perspective. Some may pose the "so what" question to this idea. Why does it matter what the participants think about the research protocol if the research is conducted ethically? Participant perceptions are central and important aspects of effective research design. This study argues comfortable, appealing protocols should positively impact voluntary compliance, long-term participation, and data integrity. Considering the current health status of the general US population, body composition assessments (and research) have huge implications. In the US between August 2021 and August 2023, the prevalence of obesity was 40.3% with the highest prevalence found among adults aged 40-59 years.[31] In children, the statistics are just as bleak. Approximately 15.1 million US children and young adults, aged 5-14 years, had overweight or obesity. Projections indicate by 2050, in most US states one in three adolescents (aged 15-24 years) will have obesity.[32] Though a small sample, the current study shows at the least that participants respond positively to body composition assessments. In keeping with the commonly reference SMART goal setting where "M" represents "measurable," body composition assessments are a step in the right direction in making positive changes.

Body composition goes beyond a simple reading or assessment of FM and FFM. However, research[33-36] points to two key predictors of longevity, VO2 max and muscle strength, which inherently have connections to body composition. More muscle mass and less fat tissue correlates with enhanced cardiorespiratory fitness (VO2 max) and muscle strength. Both are predictors of reduced all-cause mortality.[33] The current study's findings suggest when individuals perceive body composition assessments accessible and engaging, they may be more motivated to monitor and/or improve their body composition. Whether such effects translate into lasting fitness improvements and ultimately, gains in these longevity markers, remains speculative and warrants future longitudinal analysis.

The current study's findings allude to the fact that encouraging participants to engage in regular body composition assessment, utilizing instruments they deem as accurate, fun, and comfortable, may help to improve overall physical fitness. Those who seek to improve their overall body composition will arguably, in turn, improve the two key longevity metrics of VO2 max and muscle strength. Fitness professionals and researchers would do well to make note of participants' preferred means of body composition as well.

Conclusion

This qualitative pilot study explored college students' perceptions of and experiences with three commonly used body composition instruments: bioelectrical impedance analysis (BIA), digital anthropometry (DA), and hydrostatic weighing (HW). Findings indicate a general positive response to all measures with BIA identified as the most preferred. Four themes emerged from the qualitative analysis: ease of use and timely measurements, importance of accuracy, enjoyment of the assessment experience, and curiosity about the novel testing methods.

Lacking in the literature is a discussion and analysis of body composition assessment from the participant perspective. This pilot study is a first step in closing this gap. Considering the current obesity and physical inactivity epidemic facing the US, the positive results from this study offer hope for researchers and fitness professionals. Study participants valued accuracy, convenience, and comfort regarding body composition assessments. Again, this is valuable insight for future research and practical applications.

Implications from this study extend beyond basic measurements of bone, muscle, and fat. Based on the emergent themes, when individuals view body composition assessment as accurate, accessible, convenient, and even enjoyable, they may be more likely to adhere to a fitness regimen. It can further aid researchers who focus on body composition to consider participants' perceptions when designing study protocols. This offers hope to alleviate the growing health concerns facing the US.

Limitations and Future Research

The current pilot study lays the groundwork for future research to be conducted however several limitations should be noted nonetheless. First, the sample size was small (N=20) and only included participants from one university; the homogeneity (young, collegiate athletes) of the sample limits generalizability to broader populations. Moving forward, the researchers hope to include multiple universities to increase sample variability while also increasing sample size allowing for deeper analysis including differences in women's versus men's experiences. Second, participants completed the three assessments in the same order (BIA, DA, HW). Counterbalancing was not used in this study. Although methodologically ideal, the order was deliberate. Hydrostatic weighing requires complete submersion and if completed first, participants may have been wet/cold potentially compromising the accuracy and comfort of the following BIA and DA assessments. Still, future studies may explore partial counterbalancing designs. Third, social desirability bias may have affected self-reported perceptions as researchers were present in the room observing participant experiences. Delayed post-assessment data collection may help to mitigate this effect. A few modifications should also be made to the open-ended questions presented, namely, the addition of participants' major and their use (or lack of) fitness wearables. Participants who have more background information on the various body composition measures may have a different experience than those who have no knowledge of those measures. Additionally, participants who are accustomed to regular updates via fitness wearables may have a different experience with body composition compared to those who do not.

Conflict of Interest. The authors declare no conflicts of interest.

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