Bioimpedance Spectroscopy for the Health Care Professional

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Abstract

Purpose: The capstone project aimed to develop a continuing education module to educate health care providers and staff on the purpose and use of the bioimpedance spectroscopy (BIS) unit. The researcher also conducted a one-month clinical utility survey with the outpatient wound care team to determine if using the BIS measurement tool changed patient intervention plans.

Methods: The researcher developed a continuing education training module with pre-and post-testing to assess the participants learning. A course evaluation was developed to evaluate the effectiveness of the learning module. A mixed-methods clinical utility survey was performed with the outpatient wound care center where participants completed a systems usability scale (SUS) questionnaire and participated in a one–month follow-up interview.

Results: Seven subjects participated in education and demonstration training during the clinical utility survey. Four of seven participants completed the SUS questionnaire. The data revealed an above average SUS score and good learnability and usability scores.

Conclusions: The module and clinical survey confirmed that health care providers found the unit easy to operate and could potentially implement BIS into their daily workload. Reported barriers to using the device include unit location, short staffing, infection control, and patient load. Despite these barriers, the wound care staff have been trained on the device's use and found BIS beneficial for lymphedema patients, chronic venous insufficiency, congestive heart failure, kidney failure, peripheral vascular disease, and post-operative wound care needs.

Introduction

Bioimpedance spectroscopy (BIS) is a low-cost, non-invasive method for measuring body composition and fluid analysis (Khalil et al., 2014). Knowledge of body composition and fluid status aids in diagnosing and treating multiple disease processes (Khalil et al., 2014). Maintaining fluid balance is essential to maintain health and ensure all systems function properly (Khalil et al., 2014). Fluid analysis also gives a better understanding of hydration, nutrition status, and disease mechanisms (Pierson, 2003, cited in Buendia et al., 2015). BIS is a growing method for monitoring body fluid fluctuations, body composition, nutrition status, and hydration rate. However, there is little understanding of BIS's operation, use, and application with rehabilitation and wound care staff (Khalil et al., 2014). Evaluation of edema and body composition coincides with the principles of the biomechanical frame of reference (FoR). The biomechanical FoR applies to the principles of physics and the biomechanics of the human body (Cole & Tufano, 2020). Using the biomechanical FoR, therapists can choose appropriate evaluation tools to assess edema and body composition accurately.

Increasing demands for health promotion and wellness programs have accelerated the need for training of new technologies to improve the occupational therapist's ability to evaluate and treat many health conditions (Khalil et al., 2014). Body composition, fluid measurement, and edema management are critical areas in many therapy diagnoses, but these areas of practice in occupational therapy are highly specialized. The disruption of fluid balance occurs because of cancer, surgical procedures, critical illness, heart failure, and kidney failure (ImpediMed, 2020a). Body composition monitoring will promote wellness, which can help prevent a problem before it develops. BIS can measure body composition, which can contain valuable information about a patient's well-being (Asklöf et al., 2018). Using BIS monitoring for occupational therapy evaluations is congruent with the American Occupational Therapy Association's *Vision 2025* to use cost-effective, evidence-based interventions to promote health and wellness for people, populations, and communities (American Occupational Therapy Association [AOTA], 2020a).

Lymphedema is a condition that results from fluid overload in the lymphatic system, where the fluid volume is greater than the lymphatic system's transport capacity (Koelmeyer et al., 2020). Because of this overload, an abnormal accumulation of protein-rich fluid occurs in the interstitial space resulting in swelling in the extremities or other parts of the body (Koelmeyer et al., 2020). An accumulation of fluid in the interstitial space increases the extracellular fluid causing swelling (Koelmeyer et al., 2020). The evaluator can assess the extracellular fluid increase by measuring an electric signal's resistance as it passes through an extremity (Warren et al., 2007). If there is a reduced impedance measurement, this indicates the presence of extracellular fluid, which is a quantitative measurement of lymphedema called the lymphedema index (L-Dex) score (Koelmeyer et al., 2020; Warren et al., 2007). Through BIS, early detection of lymphedema through surveillance programs can help identify subclinical lymphedema, reducing the incidence of clinical lymphedema, thus reducing health care costs (Koelmeyer et al., 2020).

The newest BIS unit is a stand-on device where electrodes are stainless-steel foot and hand plates (Koelmeyer et al., 2020). The researcher's employer purchased this device for the lymphedema clinic for developing a surveillance program for subclinical lymphedema. Because this device measures fluid status and body composition, in addition to L-Dex scores, this device has the potential to provide valuable information to improve patient outcomes for more than subclinical lymphedema patients (ImpediMed, 2020b). Currently, there is one lymphedema clinician at the local hospital using the BIS unit. No other staff uses the equipment because staff members do not know or understand the BIS assessment. A crucial need exists to educate therapy staff on the BIS unit's use, the fundamental aspects, the application, and the interpretation of BIS measurements for patient diagnosis and monitoring (Khalil et al., 2014). Therefore, this capstone project aimed to develop a continuing education module to educate health care providers and staff on the purpose and use of the BIS unit to represent a health promotion attitude. The researcher conducted a one-month clinical utility survey with the wound care team to determine if the BIS measurement tool has changed their patient evaluations and interventions.

Background

The continuing education training module will occur at a local hospital licensed for 540 acute care beds with a specialized outpatient rehabilitation center, an inpatient rehabilitation hospital, and an outpatient wound care center. The leading researcher is employed in the outpatient wound care center. The outpatient wound care center treats various patient diagnoses, including lymphedema, chronic venous insufficiency, congestive heart failure, trauma, cancer, obesity, diabetes, renal failure, peripheral artery disease, coronary artery disease, human immunodeficiency virus, and substance abuse. The inpatient and outpatient adult rehabilitation centers treat various patient diagnoses, including but not limited to stroke, spinal cord injuries, neurological disorders, orthopedic injuries or surgeries, and cumulative trauma. The outpatient wound center, inpatient hospital, or outpatient rehabilitation center staff do not use the BIS equipment. Training is recommended to educate staff members on the use, application, interpretation of the BIS measurements, and how to use BIS information to formulate treatment interventions.

Research Questions

This study aims to educate staff members at a local hospital in the BIS unit's use and applications to promote health and wellness. Through the development of this training module, the researcher will evaluate the following:

1. Will health professionals who participate in the BIS training module have a better understanding of body composition and its effect on the wellness of the patient?
2. Can health professionals gain insight into a patient's health by using BIS measurements to assess body composition in outpatient wound care and outpatient rehabilitation evaluations?
3. Do health professionals change their clinical interventions when using BIS measurements as a guide for treatment and progression?

Methods

Literature Review

The acquisition of the new BIS equipment for one specialized clinic, with one employee available to use the equipment, resulted in a question of whether other employees could use the device to improve overall patient outcomes. Because of this question, the researcher conducted a needs assessment and literature review. The literature review included articles from 2005 to April 2020 using the following databases: Ovid, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Clinical Key, PubMed, Cochrane Library, and Google Scholar. The search was limited to the English language articles using the following terms combined with Boolean operators: 'bioimpedance spectroscopy,' 'theory,' 'phase angle,' 'body composition,' 'diagnosis,' 'fat mass,' 'skeletal muscle mass,' 'total body water,' 'sarcopenia,' 'congestive heart failure,' 'lymphedema,' and 'fluid composition.' Inclusion criteria consisted of randomized controlled trials, meta-analyses, systematic reviews, cohort studies, and narrative reviews, if the content discussed BIS. The search strategy excluded studies with animals.

Through the literature review, the researcher discovered several other diagnoses appropriate for BIS measurement using BIS with adhesive electrodes. BIS can be used to reduce complications associated with post-injury or post-surgical procedures, and researchers use BIS for both diagnostic and disease management purposes (Pichonnaz et al., 2015; Qin et al., 2017). Seoane et al. (2015) report using a type of BIS to assess brain damage following acute unilateral stroke. A detailed evaluation of body composition using BIS can help identify sarcopenia and osteopenia/osteoporosis (dos Santos et al., 2016; Peppa et al., 2017). Evidence also indicates that BIS helps with fluid monitoring for chronic kidney disease (CKD), pulmonary edema, and congestive heart failure (CHF) (Khalil et al., 2014; Khan et al., 2016; Weyer et al., 2014). Also, fluid management is essential for critically ill patients because fluid overload is associated with increased mortality rates (Dewitte et al., 2016). BIS monitors progress with athletes and helps with modifying training modules by monitoring athletes' fat mass, fat-free mass, and total body water (Tinsley et al., 2018). Several studies indicated BIS's use to monitor cancer-related lymphedema (Asklof et al., 2018; Kilgore et al.,2018; Qin et al., 2018; Ridner et al., 2019).

Continuing Education Module

Course Description

Following an appraisal of the evidence, the researcher determined significant value in using BIS measurements in a clinical setting. The researcher conducted a needs assessment to determine if health professionals can benefit from a BIS continuing education module to gain more insight into outpatient rehabilitation and wound care evaluations. The project aimed to provide health care professionals with the knowledge of appropriate diagnoses to be assessed with BIS and to allow the professionals to demonstrate proficiency with the BIS unit use and application. The course will be presented in a one – hour session and will consist of a slide show lecture with learning activities, BIS unit demonstration, and hands-on practice time. To assess the participants learning, there will be a pre-and post-test. At the completion of the course, each participant will be asked to complete a course evaluation to determine the learning module's effectiveness. The learning objectives for the continuing education module are stated below. Health Professionals will:

1. *Define* and *explain* bioimpedance spectroscopy (BIS) and the purpose of its use during rehabilitation evaluations.
2. *Identify* the BIS measurements and *compare* the measurements to previously used edema assessments.
3. *Select* and *identify* the appropriate patient diagnoses that would benefit from the BIS assessment.
4. *Analyze* and *examine* the relationship between fluid status monitoring, disease prevention, and how the use of BIS can improve rehabilitation outcomes.
5. *Measure* and *interpret* the BIS assessment results using a simulated rehabilitation evaluation.

Subjects

The sample population for the continuing education module is a convenience sampling of 100 therapists and health professionals who work with patients where measurement of body composition is beneficial for improved patient outcomes. Staff, including occupational therapists, physical therapists, wound therapists, wound care certified nurses, the medical director and department managers, all employed by a local hospital, will participate in the training module.

Ethical Consideration

The researcher will have safety measures in place to protect the data and confidentiality of all participants.

Preparations

The training module was written and prepared using a stand-on device (SOZO ®*;* ImpediMed Limited), a multifrequency BIS unit that provides detailed fluid and tissue analysis measurements (ImpediMed, 2020b). The company offers other fluid analysis options, but this is the only unit that measures the L-Dex score (ImpediMed, 2020b). The L-Dex score is the quantitative measurement used to identify the early onset of lymphedema in extremities. The L-Dex measurement is necessary for lymphedema patient care, which led the hospital to purchase the unit for the lymphedema clinic.

Protocol Design

The continuing education training module is a quantitative study designed for one-group with pre-and post-testing to assess the participants learning. The researcher hypothesized that through the involvement in the continuing education module, the participants would learn how to utilize the BIS unit, transfer this knowledge into the development of specific intervention programs, and perform additional research on various patient populations, promoting evidence-based practice throughout the practice setting.

Subjects will participate in the continuing education training module entitled "Bioimpedance Spectroscopy for the Healthcare Professional." The formal education module will take place in a one-hour session. Training methods will include a slide show presentation with handouts, a demonstration of the unit, and hands-on practice training. See appendix A for course description and slide show presentation. The researcher will administer a pre-and post-test to assess the participants learning (Appendix L). Following the course, each participant will submit a course evaluation (Appendix M). A written manual will be provided to the staff, including evidence-based research using the BIS unit and the training module materials. Training topics will include BIS definition, BIS appropriate patient diagnoses, and operation of the unit. The participants will demonstrate their ability to utilize the BIS unit with knowledge documentation on the demonstration check-off sheet (Appendix B). The specific measurements assessed using the BIS unit are L-Dex scores, extracellular fluid, intracellular fluid, fat mass, fat-free mass, total body water, skeletal muscle mass, hydration status, basal metabolic rate, and phase angle. The researcher will also educate participants on how the BIS data interpretation can direct treatment intervention through demonstration and clinical examples. Clinical case examples include lymphedema (Appendix D), sarcopenia (Appendix F), CHF (Appendix H), CKD (Appendix J), and general wound care population (Appendix K).

Measurement and Calculations

Participants of the training module will complete a multiple-choice pre-test to assess BIS knowledge before training. Following the pre-test administration, subjects will participate in the BIS training module. When the training module is complete, the researcher will ask the subjects to complete the same multiple-choice post-test to assess BIS follow up knowledge. The participants will be asked to complete a course evaluation to assess the effectiveness of the learning module.

Data Analysis

The researcher will use SPSS statistical software to analyze the data from the continuing education training module using a paired samples *t*-test to compare the means from the pre-and post-test data. Course evaluation means for each question will be tabulated for analysis.

Results

The purpose of this capstone project is to develop a 1.0-hour continuing education (CE) course to instruct health care providers and staff on the purpose and use of BIS for rehabilitation evaluations. The CE course will recruit 100 participants via cite sponsored education opportunity. Participants will complete a pre-and post-test and a post-course evaluation to evaluate the course instruction. The researcher will use SPSS statistical software to analyze the data from the continuing education training module using a paired samples *t*-test to compare the means from the pre-and post-test data. Course evaluation means for each question will be tabulated for analysis.

Clinical Utility Survey

Survey Description

In addition to the continuing education module, the researcher aims to determine the clinical utility of the BIS unit in the outpatient wound care center. The clinical utility survey's learning objectives are to determine if the wound care team uses the BIS machine and if they have altered their treatment interventions based on data received from the BIS assessment.

Subjects

The sample population for the clinical utility assessment is a convenience sampling of seven wound care team members, including two physical therapists, two nurses, one technician, the department manager, and the medical director. The BIS unit is located in the outpatient wound care center.

Ethical Considerations

The researcher had safety measures in place to protect the data and confidentiality of all participants.

Clinical Survey Design

The researcher conducted a mixed-methods clinical utility survey with the wound care staff. The wound care team participated in the continuing education training module as described (Appendix A). Following the educational session, the staff completed a clinical utility survey with a system usability scale (SUS) questionnaire (Appendix N). At the one-month interval, the researcher conducted interviews with the staff to determine how the staff utilized the unit, whether they altered their treatment interventions, barriers to using the device, and recommendations to increase the BIS unit's usability. The interview questions are provided in Appendix O.

Measurements and Calculations

The SUS questionnaire consisted of ten, five-point, Likert scale questions ranging from strongly disagree to strongly agree. The questionnaire was developed via the website https://www.usabilitest.com/pro/ to determine the team's usability of the unit. At the one-month interval, the team participated in an interview discussion with open-ended questions to assess how the team utilized the BIS unit within the department and if the use of treatment interventions changed since using the device.

Data Analysis

The clinical utility survey data analysis was performed via www.usabiliTEST.com. Statistics for usability and learnability are calculated based on data received from the SUS questionnaire. Qualitative data was collected from interview discussions to establish themes related to the device's use, patient diagnoses, and barriers to using the device.

Results

The SUS questionnaire was administered to the wound care team following the BIS unit's education and demonstration. The SUS data provides quantitative measurements on usability and learnability. The SUS is a 10-item questionnaire that asks participants to rank their agreement related to the BIS unit usability in a Likert scale format. Seven subjects participated in education and demonstration training. Four of seven participants completed the SUS questionnaire. Statistical results of data are included in Table 3. The SUS mean score was 83.8 (SD 11.6). The data revealed a learnability mean score of 84.4 and a usability mean score of 83.6. The SUS questionnaire is highly reliable (10 items; $\alpha = 0.855$). Table 4 shows the individual answers to each question, and Table 5 shows the individual participant's SUS score, usability rating, and learnability scores.

Interview Results

One month following the education training module, the researcher conducted an interview discussion with the participants. The participants' answers to interview questions are located on Table 6. As indicated by the participant responses, no one in the outpatient wound care center used the BIS device for patient assessments. Because the participants did not utilize the device, they could not gain insight into the patient's health or alter their treatment interventions. Critical barriers to using the device that emerged during the discussion included the device's location, impaired mobility of the patient to walk to the area, patient wounds with drainage from legs, infection control, short staffing, and no scheduled time to measure the patient. Some recommendations made by staff and management to increase the usability of the device include changing the location of the device, more discussion of its use, reminding staff, and schedule time to measure patients on a color-coded computerized scheduling system.

Discussion

In this study, the goal was to educate health professionals in BIS to measure body composition, understand appropriate diagnoses to be assessed with BIS, demonstrate an understanding of the measurements assessed, and demonstrate proficiency in BIS unit application. The feedback was positive for the SUS score, usability, and learnability being above average scores through the SUS questionnaire's clinical utility assessment. Usability refers to the participant's perceived ease of use, and learnability refers to the participant's perceived need for assistance when using the device (usabiliTEST, 2011). The overall SUS score can be translated into letter grades, where the score of 83.8 correlates with a letter grade "B" (usabiliTEST, 2011). Based on these findings, we can affirm the answer to the first research question, "will health professionals who participate in the BIS training module have a better understanding of body composition and its effect on the wellness of the patient?"

Based on the clinical utility survey's positive results, the continuing education module's expectation should also be positive, where significant learning would occur comparing the pre- and post-test average scores. The course evaluation scores are also expected to be positive, based on the SUS questionnaire's usability and learnability scores. However, a significant limitation to this project was the onset of the COVID-19 pandemic, which resulted in the cancellation of large group gatherings, which impeded the dissemination of the continuing education module.

The clinical utility survey participants were recruited based on a convenience sampling of staff in the outpatient wound care setting. Despite attendance to the education module, not all participants completed the SUS survey. However, the SUS questionnaire is reliable with small sample sizes (Sauro, 2013).

Another limitation noted in the clinical utility survey is no participant utilized the BIS device for patient evaluations. Through follow up questions, staff reported several barriers to using the device. One significant barrier reported by the staff is the location of the device. The BIS unit is located in a storage closet, and patients with functional mobility issues or those requiring assistive devices cannot make a safe transition to the scanning room.

Additionally, patients seen in the wound care department are often wrapped from the foot to the knee. Patients would be unable to walk the distance to the BIS storage closet without bandages on their feet due to severe wound drainage and decreased infection control for the patients and the staff. Also, several patients are not candidates for the screening due to wound vac placements, which could skew the results due to metal components associated with the vac.

Finally, the staff workload and short staffing limit the participants' ability to use the device. Patients in the wound care department are seen for a maximum of 30-minute appointments, including dressing removal, cleaning the wound bed and surrounding area, physician consultation with the patient, physician consultation with the health care provider, and reapplication of wound dressings/wrappings.

Despite the barriers that have impeded the device's use, the staff and manager recommend that changing the device's location could increase the usability of the BIS unit. The wound care manager reported that he could remind staff to use the device by scheduling the BIS screening on the color-coded computerized scheduling system. The wound care staff have been trained on the device's use and find that using the device is beneficial for lymphedema patients, chronic venous insufficiency, congestive heart failure, kidney failure, peripheral vascular disease, and post-operative wound care needs. Due to the high patient census, another staff member will become lymphedema certified, increasing the use of the BIS device.

The biomechanical FoR is necessary to understand the assessment process and intervention with all clients with impaired occupational performance (McMillian, 2016). Health care providers, including occupational therapists, can use assessment tools to gather objective data and use these same assessments to evaluate the effectiveness of treatment interventions and document treatment outcomes (McMillian, 2016). The biomechanical FoR is useful in assessing deficits in range of motion (ROM), muscle strength, kinematics, torque, and endurance (Cole & Tufano, 2020; McMillian, 2016). Fluid status and body composition monitoring contribute to objective data findings and help identify client factors associated with various patient diagnoses. Deficits in ROM, strength, and endurance can impact a person's ability to achieve maximum occupational performance (McMillian, 2016). Through the lens of the biomechanical FoR, using the BIS device for patient evaluations, therapists can gain valuable information about fluid status, skeletal muscle mass, and body composition that impact the patient's health and well-being. Using the BIS tool for in-depth evaluations, occupational therapists can develop more diagnosis-specific treatment interventions to maximize patient outcomes.

Occupational therapy is most understood when representing real-life situations (Dunn et al., 1994). The *Occupational Therapy Practice Framework*, 4th edition (AOTA, 2020b) has adopted five specific intervention approaches from the Ecology of Human Performance (EHP) model (Cole & Tufano, 2020). These intervention strategies help support the person, the context, the task, or a combination of all three to help the person reach their goal (Cole & Tufano, 2020).

The interventions that align with this project are *prevent* and *create*. The use of BIS for fluid status monitoring can help *prevent* problems before they arise and *create* programs help to improve the client's overall performance within their environment (Cole & Tufano, 2020). Therapists can *prevent* disability by providing interventions that can change a patient's diagnosis trajectory to improve the overall functional outcome (Dunn et al., 1994). An example of a *prevent* intervention is BIS's use for subclinical lymphedema surveillance programs (Ridner et al., 2019). Also, BIS helps monitor fluid accumulations for congestive heart failure patients to reduce hospitalizations and improve patient outcomes (Weyer et al., 2014). *Create* interventions do not assume disability is present or occurs, but therapists can provide interventions to promote improved performance within any given context (Dunn et al., 1994). Through the intervention *create*, occupational therapists can develop programs to measure fluid status and skeletal muscle mass during resistive training exercises for monitoring changes with osteoporosis and sarcopenia (dos Santos et al., 2016; Ellegård et al., 2016; Kuchnia et al., 2018; Peppa et al., 2017).

Implication for Occupational Therapy Practice

The occupational therapy profession promotes scholarly activities to gain new information, apply knowledge into practice, and engage therapists to broaden their professional development (AOTA, 2009). Through this continuing education module, the participant will learn how to utilize the BIS unit, obtain skills for implementing thorough patient evaluations, and transfer this knowledge into the development of specific intervention programs. The goal of intervention programs is to prevent exacerbations of diseases and promote overall health and wellness. Education and training are necessary to understand evaluation and treatment interventions for body composition and fluid analysis. The promotion of evidence-based practice and program development in the occupational therapy profession will answer the commitment to further developing occupational therapy foundational knowledge (AOTA, 2009). Occupational therapy supports the idea that participation in occupation promotes clients' health and well-being (AOTA, 2020b). With the guidance of combining the biomechanical FoR and the EHP model, this capstone project can contribute to health promotion and wellness for multiple disease processes through interdisciplinary approaches (AOTA, 2020a). The capstone project also supports the American Occupational Therapy Association's Vision 2025 by promoting an evidence-based and effective evaluation tool that will maximize the health and well-being of people, populations, and communities (AOTA, 2020a).

Lymphedema Treatment Intervention

An example of a preventative treatment intervention using the BIS is the Lymphedema Subclinical Lymphedema Surveillance Program. The program is appropriate for all patients with cancers associated with lymph node biopsy, trauma, or removal (Kilgore et al., 2018; Ridner et al., 2019; Shah et al., 2016). The stages of the program are:

Primary Prevention

- Baseline lymphedema measurement with BIS before cancer treatment.

Secondary Prevention

- Post-surgical lymphedema assessment every three months during the first three years.
- Post-surgical lymphedema assessment every six months during the fourth and fifth years.
- Post-surgical lymphedema assessment annually after six years.

Tertiary Prevention

- During the testing procedures, if the L-Dex score shows an increase of 6.5 over the baseline score, this indicates the presence of subclinical lymphedema, which would require the initiation of the lymphedema treatment program (Kilgore et al., 2018; Ridner et al., 2019; Shah et al., 2016).

- The lymphedema treatment program includes compression garment wear for twelve hours per day and patient-directed self-massage for four to six weeks (Kilgore et al., 2018; Ridner et al., 2019).

Ridner et al. (2019) report that subclinical lymphedema surveillance with BIS reduced the incidence of breast cancer-related lymphedema requiring costly treatment interventions.

Sarcopenia Treatment Intervention

Sarcopenia is the loss of muscle mass, which negatively impacts finances, mobility, function, quality of life, and mortality (Kuchnia et al., 2018). The elderly population will increase to three times what it is today; thus, sarcopenia is a significant health concern for the aging population (Kuchnia et al., 2018). Evaluation tools to aid in diagnosing sarcopenia are limited; therefore, it is imperative to identify the appropriate tools to measure muscle function and monitor therapy treatments (Kuchnia et al., 2018). A detailed evaluation of body composition, including fat, skeletal muscle mass, phase angle, and hydration, can help identify sarcopenia and osteopenia/osteoporosis (dos Santos et al., 2016; Peppa et al., 2017). Researchers have used BIS to measure fat mass, skeletal muscle mass, fat-free mass, phase angle, and ECF/ICF radios to identify sarcopenia. See Appendix E for specific BIS measurements used for the early identification of sarcopenia.

Congestive Heart Failure Treatment Intervention

Patients with CHF experience frequent hospitalizations due to fluid accumulations (Weyer et al., 2014). CHF treatment will be a challenge for health care companies and payers due to the large aging population (Accardi et al., 2019). Physical signs and symptoms are low indicators of cardiac decompensation or the possible need for medication management (Weyer et al., 2014). Early detection of decompensation may reduce mortality and the number of hospitalizations, therefore reducing health care costs (Weyer et al., 2014). Many tools exist to detect fluid accumulation, but there is a need for a non-invasive method for recognizing cardiac decompensation (Weyer et al., 2014). BIS is a tool used to measure fluid volume and extracellular fluid (Accardi et al., 2019; Weyer et al., 2014). Using BIS trends to monitor total body water and extracellular fluid, therapists can monitor fluid imbalances more accurately (Accardi et al., 2019). See Appendix G for specifics in CHF treatment monitoring.

Chronic Kidney Disease Treatment Intervention

The aging population is growing, and along with it, the number of associated chronic diseases, including CKD. Patients experience caloric metabolism changes in various CKD stages, decreasing muscle mass and fat mass (Arias-Guillén et al., 2018). Also, patients with CKD experience fluid overload resulting in increased hypertension in hemodialysis patients (Khan et al., 2019). Fluid overload is associated with increased cardiovascular risk and increased mortality among CKD patients (Khan et al., 2019). Monitoring fluid status is vital for CKD undergoing hemodialysis (HD) due to the absence of renal function (van der Sande et al., 2019). Patients undergoing HD can experience extreme differences between fluid overload and fluid decreases (van der Sande et al., 2019). Fluid overload leads to hypertension, while fluid depletion can lead to hypotension, tissue ischemia, and potential loss of residual renal function (van der Sande et al., 2019). See appendix I for using BIS measurements for CKD monitoring.

Conclusion

In conclusion, through the BIS continuing education module and clinical utility survey, health professionals can gain insight into the patient's health by using BIS analyses. The module and clinical survey demonstrated high usability and learnability that confirmed health care providers found the unit easy to operate and could potentially implement BIS into their daily workload. However, through the interview, we determined that the unit's location, patient mobility, infection control, and short staffing were factors that limited the device's use. The department could incorporate recommended location changes to facilitate increased BIS utilization for wound care assessments. Using BIS for lymphedema surveillance is important because the incidence of lymphedema varies with each type of cancer. Therefore, early detection of cancer-related lymphedema is the most common diagnosis assessed with the BIS unit in the outpatient wound care center. The project results suggest that further research is recommended to develop other treatment interventions for sarcopenia, CHF, and CKD. Through BIS research, interpretation of BIS information, and application of BIS measurements, therapists can develop other treatment interventions for future research in body composition and fluid analysis.

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References

Accardi, A. J., Burns, A., & Heywood, J. T. (2019). Correlation of limb bioimpedance to echocardiographic indicators of congestion in patients with NYHA class II/III heart failure. *Cardiology & Vascular Research*, *3*(1). https://doi.org/10.33425/2639-8486.1039

Adamson, P. B. (2009). Pathophysiology of the transition from chronic compensated and acute decompensated heart failure: New insights from continuous monitoring devices. *Current Heart Failure Reports*, *6*(4), 287–292. https://doi.org/10.1007/s11897-009-0039-z

American Occupational Therapy Association. (2009). Scholarship in occupational therapy. *American Journal of Occupational Therapy*, *63*(6), 790–796. https://doi.org/10.5014/ajot.63.6.790

American Occupational Therapy Association. (2013). Obesity and occupational therapy. *American Journal of Occupational Therapy*, *67*(6_Supplement), S39–S46. https://doi.org/10.5014/ajot.2013.67s39

American Occupational Therapy Association. (2015). Fact sheet: Occupational therapy's role with chronic disease management. *American Journal of Occupational Therapy*.

American Occupational Therapy Association. (2018). Role of occupational therapy in wound management. *American Journal of Occupational Therapy*, *72*(Supplement_2), 7212410057p1. https://doi.org/10.5014/ajot.2018.72s212

American Occupational Therapy Association. (2020a). *Vision 2025*. aota.org. https://www.aota.org/Publications-News/otp/Archive/2018/Vision-2025.aspx

American Occupational Therapy Association. (2020b). Occupational therapy practice framework: Domain and process – Fourth edition. *American Journal of Occupational Therapy*, *74*(Supplement_2), 7412410010p1. https://doi.org/10.5014/ajot.2020.74s2001

Arias-Guillén, M., Perez, E., Herrera, P., Romano, B., Ojeda, R., Vera, M., Ríos, J., Fontseré, N., & Maduell, F. (2018). Bioimpedance spectroscopy as a practical tool for the early detection and prevention of protein-energy wasting in hemodialysis patients. *Journal of Renal Nutrition*, *28*(5), 324–332. https://doi.org/10.1053/j.jrn.2018.02.004

Asklöf, M., Kjølhede, P., Wodlin, N. B., & Nilsson, L. (2018). Bioelectrical impedance analysis; a new method to evaluate lymphoedema, fluid status, and tissue damage after gynecological surgery - A systematic review. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *228*, 111–119. https://doi.org/10.1016/j.ejogrb.2018.06.024

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, *4*(3), 114–123.

Baumann, F. T., Reike, A., Reimer, V., Schumann, M., Hallek, M., Taaffe, D. R., Newton, R. U., & Galvao, D. A. (2018). Effects of physical exercise on breast cancer-related secondary lymphedema: A systematic review. *Breast Cancer Research and Treatment*, *170*(1), 1–13. https://doi.org/10.1007/s10549-018-4725-y

Beaudart, C., Rolland, Y., Cruz-Jentoft, A. J., Bauer, J. M., Sieber, C., Cooper, C., Al-Daghri, N., Araujo de Carvalho, I., Bautmans, I., Bernabei, R., Bruyère, O., Cesari, M., Cherubini, A., Dawson-Hughes, B., Kanis, J. A., Kaufman, J.-M., Landi, F., Maggi, S., McCloskey, E., … Fielding, R. A. (2019). Assessment of muscle function and physical performance in daily clinical practice. *Calcified Tissue International*, *105*.

Björkman, M. P., Jyväkorpi, S. K., Strandberg, T. E., Pitkala, K. H., & Tilvis, R. S. (2019). The associations of body mass index, bioimpedance spectroscopy-based calf intracellular resistance, single-frequency bioimpedance analysis and physical performance of older people. *Aging Clinical and Experimental Research*, *32*. https://doi.org/10.1007/s40520-019-01301-8

Brooke, J. (1986). *SUS -A quick and dirty usability scale*. https://hell.meiert.org/core/pdf/sus.pdf

Buendia, R., Seoane, F., Lindecrantz, K., Bosaeus, I., Gil-Pita, R., Johannsson, G., Ellegård, L., & Ward, L. C. (2015). Estimation of body fluids with bioimpedance spectroscopy: State of the art methods and proposal of novel methods. *Physiological Measurement*, *36*(10), 2171–2187. https://doi.org/10.1088/0967-3334/36/10/2171

Burton, R. F. (2019). Relationships between fat mass and lean mass. *Obesity*, *27*(6), 873–873. https://doi.org/10.1002/oby.22467

Caytak, H., Boyle, A., Adler, A., & Bolic, M. (2019). Bioimpedance spectroscopy processing and applications. *Encyclopedia of Biomedical Engineering*, *265-279*. https://doi.org/http://doi:10.1016/b978-0-12-801238-3.10884-0

Cole, M. B., & Tufano, R. (2020). *Applied theories in occupational therapy: A practical approach.* Slack.

Cole, M., & Tufano, R. (2020). Ecology of human performance. In *Applied Theories in Occupational Therapy: A practical approach*. SLACK.

Desai, A. S. (2012). Home monitoring heart failure care does not improve patient outcomes. *Circulation*, *125*(6), 828–836. https://doi.org/10.1161/circulationaha.111.031179

Dewitte, A., Carles, P., Joannès-Boyau, O., Fleureau, C., Roze, H., Combe, C., & Ouattara, A. (2015). Bioelectrical impedance spectroscopy to estimate fluid balance in critically ill patients. *Journal of Clinical Monitoring and Computing*, *30*(2), 227–233. https://doi.org/10.1007/s10877-015-9706-7 dos Santos, L., Cyrino, E. S., Antunes, M., Santos, D. A., & Sardinha, L. B. (2016). Changes in phase angle and body composition induced by resistance training in older women. *European Journal of Clinical Nutrition*, *70*(12), 1408–1413. https://doi.org/10.1038/ejcn.2016.124

Du, Z., Wan, H., Chen, Y., Pu, Y., & Wang, X. (2017). Bioimpedance spectroscopy can precisely discriminate human breast carcinoma from benign tumors. *Medicine*, *96*(4), e5970. https://doi.org/10.1097/md.0000000000005970

Dunn, W., Brown, C., & McGuigan, A. (1994). The ecology of human performance: A framework for considering the effect of context. *American Journal of Occupational Therapy*, *48*(7), 595–607. https://doi.org/10.5014/ajot.48.7.595

Ellegård, L., Bertz, F., Winkvist, A., Bosaeus, I., & Brekke, H. K. (2016). Body composition in overweight and obese women postpartum: Bioimpedance methods validated by dual energy x-ray absorptiometry and doubly labeled water. *European Journal of Clinical Nutrition*, *70*(10), 1181–1188. https://doi.org/10.1038/ejcn.2016.50

Fazio, L. S. (2017a). *Developing occupation-centered programs with the community*. Slack Incorporated.

Fazio, L. S. (2017b). Practicing occupation in the community. In *Developing occupation-centered programs with the community*. SLACK incorporated.

Fisch, B. J., & Spiegel, D. M. (1996). Assessment of excess fluid distribution in chronic hemodialysis patients using bioimpedance spectroscopy. *Kidney International*, *49*(4), 1105–1109. https://doi.org/10.1038/ki.1996.160

Funk, M., Nystrom, K. V., Hutchinson, C., Katz, S. D., & Lee, F. A. (2003). Bioimpedance monitoring in patients with chronic heart failure. *Journal of Cardiac Failure*, *9*(5), S6. https://doi.org/10.1016/s1071-9164(03)00177-5

Gillen, G., & Nilsen, D. M. (2019). Motor function and occupational performance. In *Willard and Spackman's Occupational Therapy*. Wolters Kluwer.

Gillespie, T. C., Sayegh, H. E., Brunelle, C. L., Daniell, K. M., & Taghian, A. G. (2018). Breast cancer-related lymphedema: Risk factors, precautionary measures, and treatments. *Gland Surgery*, *7*(4), 379–403. https://doi.org/10.21037/gs.2017.11.04

Gillham, M. B., Hodges, V. A., Davis, J. N., & Meadows, M. R. (2005). Quantifying excess fat free mass in overweight/obese adults. *Journal of the American Dietetic Association*, *105*(8), 17. https://doi.org/10.1016/j.jada.2005.05.046

Han, B.-G., Lee, J., Kim, J.-S., & Yang, J.-W. (2018). Clinical significance of phase angle in non-dialysis CKD stage 5 and peritoneal dialysis patients. *Nutrients*, *10*(9), 1331. https://doi.org/10.3390/nu10091331

Hidding, J. T., Viehoff, P. B., Beurskens, C. H. G., van Laarhoven, H. W. M., Nijhuis-van der Sanden, M. W. G., & van der Wees, P. J. (2016). Measurement properties of instruments for measuring of lymphedema: Systematic review. *Physical Therapy*, *96*(12), 1965–1981. https://doi.org/10.2522/ptj.20150412

Impedimed. (2017). *Training Material | ImpediMed*. www.impedimed.com. https://www.impedimed.com/training/

Impedimed. (2018a). Bioimpedance drawing. In *https://i.ytimg.com/vi/BPpbOoD1Spg/maxresdefault.jpg*.

ImpediMed. (2018b). *Tissue and fluid analysis*. PowerPoint Slides. www.hellosozo.com

ImpediMed. (2018c). What is BIS? - SOZO® digital health platform [YouTube Video]. In *YouTube*. https://www.youtube.com/watch?v=BPpbOoD1Spg&t=15s

ImpediMed. (2020a). *Bioimpedance spectroscopy (BIS) technology | impedimed*. Www.Impedimed.Com. https://www.impedimed.com/healthcare/bis-technology/

ImpediMed. (2020b). *Products | ImpediMed*. Www.Impedimed.Com. https://www.impedimed.com/products/

ImpediMed. (2020c). SOZO unit. In *https://www.impedimed.com/healthcare/*.

Jack, J., & Estes, R. I. (2010). Documenting progress: Hand therapy treatment shift from biomechanical to occupational adaptation. *American Journal of Occupational Therapy*, *64*(1), 82–87. https://doi.org/10.5014/ajot.64.1.82

Janssen, I., Heymsfield, S. B., Wang, Z., & Ross, R. (2000). Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. *Journal of Applied Physiology*, *89*(1), 81–88. https://doi.org/10.1152/jappl.2000.89.1.81

Joskova, V., Patkova, A., Havel, E., Najpaverova, S., Uramova, D., Kovarik, M., Zadak, Z., & Hronek, M. (2019). The bioimpedance spectroscopy as useful tool for measuring the fluid excess and fluid management in severe polytrauma patients. *Physiological Research*, 255–264. https://doi.org/10.33549/physiolres.933953

Kataoka, H. (2009). Novel monitoring method for the management of heart failure: Combined measurement of body weight and bioimpedance index of body fat percentage. *Future Cardiology*, *5*(6), 541–546. https://doi.org/10.2217/fca.09.47

Kaysen, G. A., Zhu, F., Sarkar, S., Heymsfield, S. B., Wong, J., Kaitwatcharachai, C., Kuhlmann, M. K., & Levin, N. W. (2005). Estimation of total-body and limb muscle mass in hemodialysis patients by using multifrequency bioimpedance spectroscopy. *The*

American Journal of Clinical Nutrition, *82*(5), 988–995. https://doi.org/10.1093/ajcn/82.5.988

Keane, D. F., Baxter, P., Lindley, E., Moissl, U., Pavitt, S., Rhodes, L., & Wieskotten, S. (2017). The body composition monitor: A flexible tool for routine fluid management across the hemodialysis population. *Biomedical Physics & Engineering Express*, *3*(3), 035017. https://doi.org/10.1088/2057-1976/aa6f45

Kenworthy, P., Grisbrook, T. L., Phillips, M., Gittings, P., Wood, F. M., Gibson, W., & Edgar, D. W. (2017). Bioimpedance spectroscopy: A technique to monitor interventions for swelling in minor burns. *Burns*, *43*(8), 1725–1735. https://doi.org/10.1016/j.burns.2017.04.022

Kenworthy, P., Phillips, M., Grisbrook, T. L., Gibson, W., Wood, F. M., & Edgar, D. W. (2018). Monitoring wound healing in minor burns—A novel approach. *Burns*, *44*(1), 70–76. https://doi.org/10.1016/j.burns.2017.06.007

Khalil, S., Mohktar, M., & Ibrahim, F. (2014). The theory and fundamentals of bioimpedance analysis in clinical status monitoring and diagnosis of diseases. *Sensors*, *14*(6), 10895–10928. https://doi.org/10.3390/s140610895

Khan, A., Khan, A. H., Adnan, A. S., Sulaiman, S. A. S., Ahmad, N., & Gan, S. H. (2018). Evaluation of factors affecting time to achieve dry weight among hemodialysis patients using bioimpedance spectroscopy. *Irish Journal of Medical Science (1971 -)*, *188*(1), 311–319. https://doi.org/10.1007/s11845-018-1813-2

Khan, Y. H., Sarriff, A., Adnan, A. S., Khan, A. H., & Mallhi, T. H. (2016). Diuretics prescribing in chronic kidney disease patients: Physician assessment versus bioimpedance spectroscopy. *Clinical and Experimental Nephrology*, *21*(3), 488–496. https://doi.org/10.1007/s10157-016-1303-7

Kilgore, L. J., Korentager, S. S., Hangge, A. N., Amin, A. L., Balanoff, C. R., Larson, K. E., Mitchell, M. P., Chen, J. G., Burgen, E., Khan, Q. J., O'Dea, A. P., Nye, L., Sharma, P., & Wagner, J. L. (2018). Reducing breast cancer-related lymphedema (BCRL) through prospective surveillance monitoring using bioimpedance spectroscopy (BIS) and patient directed self-interventions. *Annals of Surgical Oncology*, *25*(10), 2948–2952. https://doi.org/10.1245/s10434-018-6601-8

Kim, E. J., Choi, M. J., Lee, J. H., Oh, J. E., Seo, J. W., Lee, Y. K., Yoon, J. W., Kim, H. J., Noh, J. W., & Koo, J. R. (2017). Extracellular fluid/intracellular fluid volume ratio as a novel risk indicator for all-cause mortality and cardiovascular disease in hemodialysis patients. *PLOS ONE*, *12*(1), e0170272. https://doi.org/10.1371/journal.pone.0170272

Kittiskulnam, P., Chertow, G. M., Carrero, J. J., Delgado, C., Kaysen, G. A., & Johansen, K. L. (2017). Sarcopenia and its individual criteria are associated, in part, with mortality among patients on hemodialysis. *Kidney International*, *92*(1), 238–247. https://doi.org/10.1016/j.kint.2017.01.024

Klug, B. (2017). An overview of the system usability scale in library website and system usability testing. *Weave: Journal of Library User Experience*, *1*(6). https://doi.org/10.3998/weave.12535642.0001.602

Koelmeyer, L. A., Ward, L. C., Dean, C., & Boyages, J. (2020). Body positional effects on bioimpedance spectroscopy measurements for lymphedema assessment of the arm. *Lymphatic Research and Biology*, *18*(1). https://doi.org/10.1089/lrb.2019.0067

Kuchnia, A. J., Yamada, Y., Teigen, L., Krueger, D., Binkley, N., & Schoeller, D. (2018). Combination of DXA and BIS body composition measurements is highly correlated with physical function—an approach to improve muscle mass assessment. *Archives of Osteoporosis*, *13*(1). https://doi.org/10.1007/s11657-018-0508-7

Lattie, E. G., Bass, M., Garcia, S. F., Phillips, S. M., Moreno, P. I., Flores, A. M., Smith, J., Scholtens, D., Barnard, C., Penedo, F. J., Cella, D., & Yanez, B. (2020). Optimizing health information technologies for symptom management in cancer patients and survivors: Usability evaluation. *JMIR Formative Research*, *4*(9), e18412. https://doi.org/10.2196/18412

Levenhagen, K., Davies, C., Perdomo, M., Ryans, K., & Gilchrist, L. (2017). Diagnosis of upper quadrant lymphedema secondary to cancer: Clinical practice guideline from the oncology section of the American physical therapy association. *Physical Therapy*, *97*(7), 729–745. https://doi.org/10.1093/ptj/pzx050

McMillian, I. R. (2016, September 9). *The biomechanical frame of reference in occupational therapy*. Musculoskeletal key. https://musculoskeletalkey.com/the-biomechanical-frame-of-reference-in-occupational-therapy/

Merks, P., Religioni, U., Arciszewska, K., Pankiewicz, W., Jaguszewski, M., & Vaillancourt, R. (2020). Usability testing and satisfaction of “The Patient Access”: A mobile health application for patients with venous thromboembolic disease. A pilot study. *Cardiology Journal*. https://doi.org/10.5603/cj.a2020.0107

Minett, M. M., Binkley, T. L., Holm, R. P., Runge, M., & Specker, B. L. (2020). Feasibility and effects on muscle function of an exercise program for older adults. *Medicine & Science in Sports & Exercise*, *52*(2), 441–448. https://doi.org/10.1249/mss.0000000000002152

Moloney, E. C., Brunner, M., Alexander, A. J., & Clark, J. (2014). Quantifying fibrosis in head and neck cancer treatment: An overview. *Head & Neck*, *37*(8), 1225–1231. https://doi.org/10.1002/hed.23722

Moon, J. R., Smith, A. E., Tobkin, S. E., Lockwood, C. M., Kendall, K. L., Graef, J. L., Roberts, M. D., Dalbo, V. J., Kerksick, C. M., Cramer, J. T., Beck, T. W., & Stout, J. R. (2009). Total body water changes after an exercise intervention tracked using bioimpedance spectroscopy: A deuterium oxide comparison. *Clinical Nutrition*, *28*(5), 516–525. https://doi.org/10.1016/j.clnu.2009.04.025

Naranjo-Hernández, D., Reina-Tosina, J., & Min, M. (2019). Fundamentals, recent advances, and future challenges in bioimpedance devices for healthcare applications. *Journal of Sensors*, *2019*, 1–42. https://doi.org/10.1155/2019/9210258

National Institute on Health. (2019). *Assessing your weight and health risk*. Nih.Gov. https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm

Nicholls, G. M., & Richards, M. A. (2007). Disease monitoring of patients with chronic heart failure. *Heart*, *93*(4), 519–523. https://doi.org/10.1136/hrt.2005.078519

Norberg, E.-B., Boman, K., Löfgren, B., & Brännström, M. (2014). Occupational performance and strategies for managing daily life among the elderly with heart failure. *Scandinavian Journal of Occupational Therapy*, *21*(5), 392–399. https://doi.org/10.3109/11038128.2014.911955

Nussbaum, J., & Garcia, R. K. (2009). Restorative physical and occupational therapy: A critical need for patients with chronic kidney and end-stage renal disease. *Advances in Chronic Kidney Disease*, *16*(6), 529–535. https://doi.org/10.1053/j.ackd.2009.08.001

Padwal, R., Majumdar, S. R., & Leslie, W. D. (2016). Relationship among body fat percentage, body mass index, and all-cause mortality. *Annals of Internal Medicine*, *165*(8), 604. https://doi.org/10.7326/l16-0334

Peppa, M., Stefanaki, C., Papaefstathiou, A., Boschiero, D., Dimitriadis, G., & Chrousos, G. (2017). Bioimpedance analysis vs. DEXA as a screening tool for osteosarcopenia in lean, overweight and obese Caucasian postmenopausal females. *HORMONES*, *16*(2). https://doi.org/10.14310/horm.2002.1732

Pichler, G. P., Amouzadeh-Ghadikolai, O., Leis, A., & Skrabal, F. (2013). A critical analysis of whole body bioimpedance spectroscopy (BIS) for the estimation of body compartments in health and disease. *Medical Engineering & Physics*, *35*(5), 616–625. https://doi.org/10.1016/j.medengphy.2012.07.006

Pichonnaz, C., Bassin, J. P., Lécureux, E., Currat, D., & Jolles, B. M. (2015). Bioimpedance spectroscopy for swelling evaluation following total knee arthroplasty: A validation study. *BMC Musculoskeletal Disorders*, *16*(1). https://doi.org/10.1186/s12891-015-0559-5

Qin, E. S., Bowen, M. J., & Chen, W. F. (2018). Diagnostic accuracy of bioimpedance spectroscopy in patients with lymphedema: A retrospective cohort analysis. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *71*(7), 1041–1050. https://doi.org/10.1016/j.bjps.2018.02.012

Reitz, S. M., & Scaffa, M. E. (2020). Occupational therapy in the promotion of health and well-being. *American Journal of Occupational Therapy*, *74*(3), 7403420010p1. https://doi.org/10.5014/ajot.2020.743003

Rice University. (2013, March 6). *26.1 body fluids and fluid compartments – anatomy and physiology*. Opentextbc.Ca. https://opentextbc.ca/anatomyandphysiology/chapter/26-1-body-fluids-and-fluid-compartments/

Ridner, S. H., Dietrich, M. S., Cowher, M. S., Taback, B., McLaughlin, S., Ajkay, N., Boyages, J., Koelmeyer, L., DeSnyder, S. M., Wagner, J., Abramson, V., Moore, A., & Shah, C. (2019). A randomized trial evaluating bioimpedance spectroscopy versus tape measurement for the prevention of lymphedema following treatment for breast cancer: Interim analysis. *Annals of Surgical Oncology*, *26*(10), 3250–3259. https://doi.org/10.1245/s10434-019-07344-5

Rural Health Information Hub. (2011). *Defining health promotion and disease prevention - rhihub toolkit*. Ruralhealthinfo.Org. https://www.ruralhealthinfo.org/toolkits/health-promotion/1/definition

Ryan, A. M., Prado, C. M., Sullivan, E. S., Power, D. G., & Daly, L. E. (2019). Effects of weight loss and sarcopenia on response to chemotherapy, quality of life, and survival. *Nutrition*, *67–68*, 110539. https://doi.org/10.1016/j.nut.2019.06.020

Samson, K. (2019). Bioimpedance spectroscopy tracks lymphedema more accurately. *Oncology Times*, *41*(12), 18. https://doi.org/10.1097/01.cot.0000569284.27775.14

Sandek, A., & Rauchhaus, M. (2007). Use of bioimpedance analysis in patients with chronic heart failure? *European Journal of Heart Failure*, *9*(1), 105–105. https://doi.org/10.1016/j.ejheart.2006.10.009

Sauro, J. (2013). *MeasuringU: 10 things to know about the system usability scale (SUS)*. measuringu.com. https://measuringu.com/10-things-sus/

Savarese, G., & Lund, L. H. (2017). Global public health burden of heart failure. *Cardiac Failure Review*, *03*(01), 7. https://doi.org/10.15420/cfr.2016:25:2

Schell, B. A., & Gillen, G. (2019). *Willard and Spackman's occupational therapy*. Wolters Kluwer.

Seoane, F., Reza Atefi, S., Tomner, J., Kostulas, K., & Lindecrantz, K. (2015). Electrical bioimpedance spectroscopy on acute unilateral stroke patients: Initial observations regarding differences between sides. *BioMed Research International*, *2015*, 1–12. https://doi.org/10.1155/2015/613247

Serra-Prat, M., Lorenzo, I., Palomera, E., Ramírez, S., & Yébenes, J. C. (2018). Total body water and intracellular water relationships with muscle strength, frailty and functional performance in an elderly population. A cross-sectional study. *The Journal of Nutrition, Health & Aging*, *23*(1), 96–101. https://doi.org/10.1007/s12603-018-1129-y

Seward, C., Skolny, M., Brunelle, C., Asdourian, M., Salama, L., & Taghian, A. G. (2016). A comprehensive review of bioimpedance spectroscopy as a diagnostic tool for the detection and measurement of breast cancer-related lymphedema. *Journal of Surgical Oncology*, *114*(5), 537–542. https://doi.org/10.1002/jso.24365

Shah, C., Vicini, F. A., & Arthur, D. (2016). Bioimpedance spectroscopy for breast cancer related lymphedema assessment: Clinical practice guidelines. *The Breast Journal*, *22*(6), 645–650. https://doi.org/10.1111/tbj.12647

Soran, A., Ozmen, T., McGuire, K. P., Diego, E. J., McAuliffe, P. F., Bonaventura, M., Ahrendt, G. M., DeGore, L., & Johnson, R. (2014). The importance of detection of subclinical lymphedema for the prevention of breast cancer-related clinical lymphedema after axillary lymph node dissection; A prospective observational study. *Lymphatic Research and Biology*, *12*(4), 289–294. https://doi.org/10.1089/lrb.2014.0035

Steinwandel, U., Gibson, N., Towell-Barnard, A., Parsons, R., Rippey, J., & Rosman, J. (2019). Does the intravascular volume status in hemodialysis patients measured by inferior vena cava ultrasound correlate with bioimpedance spectroscopy? *Journal of Clinical Nursing*, *28*(11–12), 2135–2146. https://doi.org/10.1111/jocn.14804

Stern, B. Z. (2018). Critical reflections on self-management support in chronic disease: The value of occupational therapy in health promotion. *The Open Journal of Occupational Therapy*, *6*(4). https://doi.org/10.15453/2168-6408.1461

St. Onge, M.-P., Wang, J., Shen, W., Wang, Z., Allison, D. B., Heshka, S., Pierson, R. N., & Heymsfield, S. B. (2004). Dual-Energy x-ray absorptiometry-measured lean soft tissue mass: Differing relation to body cell mass across the adult life span. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *59*(8), B796–B800. https://doi.org/10.1093/gerona/59.8.b796

Tinsley, G. M., Graybeal, A. J., Moore, M. L., & Nickerson, B. S. (2019). Fat-free mass characteristics of muscular physique athletes. *Medicine & Science in Sports & Exercise*, *51*(1), 193–201. https://doi.org/10.1249/mss.0000000000001749

Tinsley, G. M., Morales, E., Forsse, J., & Grandjean, P. W. (2017). Impact of acute dietary manipulations on DXA and BIA body composition estimates. *Medicine & Science in Sports & Exercise*, *49*(4), 823–832. https://doi.org/10.1249/mss.0000000000001148

Tsuchiya, M., Mori, M., Takahashi, M., & Masujima, M. (2018). Community-based lymphedema risk reduction programs for cancer survivors: An Internet survey of public health nurses. *Japan Journal of Nursing Science*, *15*(4), 340–350. https://doi.org/10.1111/jjns.12204

Turpin, M., & Iwama, M. K. (2011). *Using occupational therapy models in practice : a field guide*. Elsevier.

Uemura, K., Doi, T., Tsutsumimoto, K., Nakakubo, S., Kim, M., Kurita, S., Ishii, H., & Shimada, H. (2019). Predictivity of bioimpedance phase angle for incident disability in older adults. *Journal of Cachexia, Sarcopenia and Muscle*, *11*. https://doi.org/10.1002/jcsm.12492

usabiliTEST. (2011). *Usability testing and information architecture tools for everyone*. Www.Usabilitest.Com. https://www.usabilitest.com/pro/?ux=Bl4ONgAQFRl7T1dFRV5URB8RVhYXf3YPV1IBBgEQN1wHRmcHFhczXEdMXkNACgAVSg1cEl5CU1AKBjo3NDZmMWJiNQ%3D%3D

Vance, K., Miller, C., & McGlamery, J. N. (2020). Improving outcomes in chronic conditions: Occupational therapy's distinct value in PDGM. *SIS Quarterly Practice Connections*, *5*(2), 15–18.

van der Sande, F. M., van de Wal-Visscher, E. R., Stuard, S., Moissl, U., & Kooman, J. P. (2019). Using bioimpedance spectroscopy to assess volume status in dialysis patients. *Blood Purification*, *49*(1–2), 178–184. https://doi.org/10.1159/000504079

Walowski, C. O., Braun, W., Maisch, M. J., Jensen, B., Peine, S., Norman, K., Müller, M. J., & Bosy-Westphal, A. (2020). Reference values for skeletal muscle mass – current concepts and methodological considerations. *Nutrients*, *12*(3), 755. https://doi.org/10.3390/nu12030755

Ward, L. C., Czerniec, S., & Kilbreath, S. L. (2008). Quantitative bioimpedance spectroscopy for the assessment of lymphoedema. *Breast Cancer Research and Treatment*, *117*(3), 541–547. https://doi.org/10.1007/s10549-008-0258-0

Ward, L. C., Dylke, E. S., & Kilbreath, S. L. (2012). Measurement of hand volume by bioelectrical impedance spectroscopy. *Lymphatic Research and Biology*, *10*(2), 81–86. https://doi.org/10.1089/lrb.2012.0005

Warren, A. G., Brorson, H., Borud, L. J., & Slavin, S. A. (2007). Lymphedema. *Annals of Plastic Surgery*, *59*(4), 464–472. https://doi.org/10.1097/01.sap.0000257149.42922.7e

Warren, A. G., Janz, B. A., Slavin, S. A., & Borud, L. J. (2007). The use of bioimpedance analysis to evaluate lymphedema. *Annals of Plastic Surgery*, *58*(5), 541–543. https://doi.org/10.1097/01.sap.0000244977.84130.cf

Weyer, S., Zink, M. D., Wartzek, T., Leicht, L., Mischke, K., Vollmer, T., & Leonhardt, S. (2014). Bioelectrical impedance spectroscopy as a fluid management system in heart failure. *Physiological Measurement*, *35*(6), 917–930. https://doi.org/10.1088/0967-3334/35/6/917

World Health Organization: WHO. (2019, November 15). *Health promotion*. Who.Int; World Health Organization: WHO. https://www.who.int/health-topics/health-promotion#tab=tab_1

Yanek, L. R., Vaidya, D., Kral, B. G., Dobrosielski, D. A., Moy, T. F., Stewart, K. J., & Becker, D. (2015). Lean mass and fat mass as contributors to physical fitness in an overweight and obese African American population. *Ethn Dis.*, *25*(2), 214–219.

Yoo, C., Kim, J., Yang, Y., Lee, J., & Jeon, G. (2016). Bioelectrical impedance analysis for severe stroke patients with upper extremity hemiplegia. *Journal of Physical Therapy Science*, *28*(10), 2708–2712. https://doi.org/10.1589/jpts.28.2708-2712

Yu, C. M., Wang, L., Chau, E., Chan, R. H. W., Kong, S. L., Tang, M. O., Christensen, J., Stadler, R. W., & Lau, C.-P. (2005). Intrathoracic impedance monitoring in patients with heart failure. *Circulation*, *112*(6), 841–848. https://doi.org/10.1161/circulationaha.104.492207

Bioimpedance Spectroscopy for the Health Care Professional Results

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List of Appendices

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Appendices

Table 1: Needs Assessment for Bioimpedance for the Health Care Professional
Completed 03/20/2020

Clinical Question of Concern under Investigation:

1. **Will health professionals who participate in the bioimpedance spectroscopy (BIS) training module have a better understanding of body composition and its effect on the wellness of the patient?**
2. **Can health professionals gain insight into a patient's health by using BIS measurements to assess body composition in outpatient wound care and outpatient rehabilitation evaluations?**
3. **Do health professionals change their clinical interventions when using BIS measurements as a guide for treatment and progression?**

Current Outcomes: How things are…	Desired Outcomes: How things should be…	Needs: What is the source of the problem?	Evidence: What does the best available evidence tell us?	Project Steps: What are we going to do about it?	Evaluation Items: How do we measure indications of project success?
• **The Health Professionals at Hendrick Medical Center do not measure body composition or fluid status.** • **Health Care professionals at Hendrick Medical Center are not informed on the use, indicators, or the justification of using the bioimpedance**	• The knowledge of body composition and fluid status aids in the diagnosis and treatment of multiple disease processes and improves wound healing (Kenworthy et al., 2018). • Maintaining fluid balance is essential to maintain health and ensure all systems	• Increased demand for health promotion and wellness programs exists (Fazio, 2017). • Need for the training of new technologies to improve the health professional's ability to evaluate and treat many health conditions (Khalil et al.,	• The disruption of fluid balance occurs because of cancer, surgical procedures, critical illness, heart failure, and kidney failure (Impedimed, 2019). • BIS is a method for monitoring body fluid fluctuations, body composition, nutrition status, and hydration rate (Khalil et al., 2014). • Edema reduction is critical in wound healing and post-surgical interventions (Kenworthy et al.,	• Perform a literature review • Perform needs assessment • Determine the guiding frame of reference and practice model. • Write background and introduction • Create course outline, objectives, and syllabus • Develop a	• Course evaluation • Pretest/posttest • Paired samples *t*-test to compare mean scores of pre-posttests to demonstrate improved knowledge of BIS measurements. • Clinical Utility Survey to determine the effectiveness of BIS measurements

spectroscopy (BIS) unit. • **Health Care Professionals at the Hendrick Outpatient wound care center do not evaluate fluid status and body composition and are also not informed of BIS technology.** • **Currently, BIS is used to identify early stages of lymphedema (Soran et al., 2014).** • **BIS can detect small changes in extracellular fluid resulting in early detection of lymphedema (Soran et al., 2014).**	function properly (Khalil et al., 2014). • BIS can help improve the overall functional outcome for patients with multiple diagnoses and decrease the incidence of lymphedema (Impedimed, 2020). • BIS monitoring will promote wellness, which can help prevent a problem before it develops (Asklöf et al., 2018).	2014). • Research is necessary to understand body composition and fluid analysis (Khalil et al., 2014). • BIS is a new technology for Hendrick Medical Center Wound Center. • The staff has not received education on BIS. • There is a crucial need to educate therapy staff on the use of the BIS unit, the fundamental aspects, and the applications of BIS for patient diagnosis and monitoring (Khalil et al., 2014).	2018; Pichonnaz et al., 2015). • Prolonged, standing edema can impact patients' function by limiting the range of motion, causing pain, and decreasing wound healing (Kenworthy et al., 2017). • Body composition contains valuable information about patients' well-being by identifying changes in total body volume, body cell mass, fat mass, fat-free mass, extracellular fluid volume, and intracellular fluid volume (Asklöf et al., 2018). • Any abnormal loss in muscle or bone mass and unbalanced fluids are predictors of the healthiness of the human body (Khalil et al., 2014). • BIS can help identify certain disorders such as sarcopenia and osteopenia/osteoporos is (dos Santos et al.,	training module to educate health care professionals in the use of BIS for multiple patient populations. • Develop pre/posttest for participant assessment of knowledge. • Create a course evaluation • Formulate clinical utility survey for wound care team with Likert type usability scale • Determine methods for analysis • Implement program • Analyze results • Discuss the conclusion • The proposed	for patient treatment interventions in the outpatient wound care center. • Usability Likert scale • Interview participants for qualitative data • Poster presentation

			2016; Peppa et al., 2017). • Allows for appropriate evaluation of progress with athletes and helps with the modification of training modules (Tinsley et al., 2018).	training module will serve the occupational therapy community by satisfying the demand for a valid, affordable, and user-friendly method for measuring body composition and fluid analysis. • Using BIS promotes wellness, health promotion, and evidence-based practice.	

Table 2: Evidence Table

Authors, Year, Location	Hypothesis or Purpose	Study Design, Intervention, Outcome Measures and Level of Evidence	Study Populations or Groups	Results	Significance of these findings to OT	Study Limitations
Asklöf, Kjølhede, Wodlin, & Nilsson (2018) Sweden https://doi.org/10.1016/j.ejogrb.2018.06.024	To summarize the current knowledge of non-invasive bioelectrical impedance analysis (BIA) used with gynecological surgical patients. Assessed post-operative development of lymphedema and to determine if a fluid imbalance is a factor in cancer mortality and predictor of complications.	Study design: Systematic review Intervention: Pub Med, MEDLINE, Scopus Web of Science, Cochrane Library Outcomes: Post-operative development of lower limb lymphedema, perioperative hydration measuring, BIA parameter phase angle as a prognostic factor in cancer survival, and predictive for post-operative complications. Evidence Level: I	Thirty-seven articles were evaluated. 16 studies on BIA relating to gynecological surgical patients. These were divided into three groups: BIA and lower limb lymphedema (n=7), BIA and perioperative hydration measuring (n=3), and phase angle as a prognostic factor in cancer survival and as a predictive for post-operative complications (n=6).	BIA was found to detect lymphedema with a sensitivity of 73% and specificity of 84%. Studies indicate that BIA could detect lower limb lymphedema at an early stage before it was clinically detectable. An increase in extracellular fluid volume related to total body fluid volume and a decrease in phase angle was associated with a higher occurrence of post-operative complications. Low phase angle values were also associated with increased mortality in cancer patients.	The use of BIA is a useful tool in the clinical setting for the detection of lymphedema.	Cut off-limits within study populations. Reference values for the general population need to be defined. There are few studies on the gynecological study population. There is a need for further research on gynecological surgery on lower limb lymphedema, perioperative fluid balance, and post-operative complications.
Buendia, Seoane, Lindecrantz, Bosaeus, Gil-Pita, Johannsson, . . . Ward (2015)	To review the robustness and validity of the methods used with Bioimpedance spectroscopy (BIS) when estimating	Study design: A cohort study comparing the accuracy of existing BIS approaches and the newly proposed approaches to isotope dilution methods, which are considered the	Five different BIS methods were compared on a database of patients receiving growth hormone replacement therapy containing isotope dilution methods.	New methods performed best overall for predicting all fluid compartment volumes; the difference between methods is small.	BIS can be used in several fields for prevention to include nutrition, renal failure, cancer, lymphedema.	The source of improvement in prediction for each method is unclear.

https://doi.org/10.1088/0967-3334/36/10/2171 **Sweden**	fluid volume.	cold standard in body fluid estimation. Intervention: none Outcomes: BIS measurements were compared to isotope dilution methods Evidence Level: II	BIS data, total body water, intracellular water, and extracellular water measurements were obtained for 339 subjects measured.			
Caytak, Boyle, Adler, & Bolic (2019) https://doi.org/10.1016/b978-0-12-801238-3.10884-0 **Ottawa, ON, Canada**	Aim to provide an overview and framework for processing raw impedance measurements and describe factors that affect processing methods.	Study design: Descriptive study Intervention: none Outcomes: Sources of inaccuracy, modeling, data classification Evidence Level: V	Types of systemic and random measurement errors were discussed. BIS processing steps, types of errors, modeling, denoising, data classification sequence	Overview of processing steps for BIS data was discussed.	BIS can be used in the clinical setting for human body composition monitoring and with other diagnosis classifications for various pathologies.	Larger studies will allow for applying advanced learning techniques with increase available data.
France **Dewitte, Carles, Joannes-Boyau, Fleureau, Roze, Combe, & Ouattara (2015)** **https://doi.org/10.1007/s10877-015-9706-7** **France**	Evaluate the feasibility and reproducibility of BIS in critically ill patients and compared to fluid balance and daily changes in total body water measured by BIS.	Study design: observational study Intervention: BIS measurements Outcomes: weight and height measurements, calculation of fluid balance, bioimpedance measurements to include quality index, total body water, extracellular water, intracellular water, fluid overload, lean tissue index, and fat tissue index. Evidence Level: III	During a 12-month period, all patients admitted to the ICU and required mechanical ventilation were prospectively enrolled. Twenty-five patients were included in the study. Fluid balance and BIS measurements were taken on three consecutive days. Correlation between fluid balance and daily changes in body weight and BIS measurements.	Non-invasive determination of body water composition using BIS is feasible in critically ill patients but requires knowledge of patients' weight.	Correct assessment of fluid status in critically ill patients and reducing the fluid is essential in the resuscitation of patients and has been proven to reduce sepsis mortality.	The study is observational Fluid balance and body weight changes are crude determinates of body water and inadequate evaluation criteria in critically ill patients, but these methods are used daily for ICU patients. The study did not evaluate the insensible fluid loss. Patients were not weighed in an electronic bed. The accuracy of the BIS could have been minimized due to the

						inclusion criteria of the patient population.
Dos Santos, L., Cyrino, Antunes, Santos, D.A., & Sardinha (2016) [**https://doi.org/10.1038/ejcn.2016.124**](https://doi.org/10.1038/ejcn.2016.124) **Portugal**	To describe the effect of resistance training (RT) in training, retraining, and detraining on body composition, including phase angle (PhA) in older women.	Study design: longitudinal study Intervention: 44 weeks of total: 12 weeks of RT, 12 weeks of detraining, 12 weeks of retraining, and eight weeks of measurements. Outcomes: muscular strength, dietary intake, BMI, body composition, BIS for PhA. Evidence Level: III	33 older women age $\geq$ 60 years volunteered to participate in the study.	In untrained older women, RT is associated with increases in PhA whereas detraining decreases PhA.	IT is recommended that women engage in RT regime to achieve a healthier body and avoid long periods of inactivity. PhA has been set as a predictive indicator for sarcopenia, muscle function, fragility, and mortality risk. It is an indicator of hydration and nutritional status.	
Du, Wan, Chen, Pu, & Wang (2019) [**https://doi.org/10.1097/md.0000000000005970**](https://doi.org/10.1097/md.0000000000005970) **China**	To investigate the diagnostic value of BIS in breast tumors.	Study design: diagnostic accuracy study Intervention: BIS measurements Outcomes: The resistance under direct current, the resistance under alternating current with max frequency, the frequency at highest resistance, and the dispersion coefficient. Evidence Level: III	Collected and measured 976 breast tissues, including 581 breast cancers, 190 benign tumors, and 205 normal mammary gland tissues.	The results of the study indicate BIS can discriminate breast tumors. According to the study, applying the diagnostic criteria, almost no benign tumor would go misdiagnosed, and nearly 70% of cancer patients would undergo a second operation, but ¼ of cancer patients would still require frozen section diagnosis.	Can BIS be used for special testing for the breast patient population?	More accurate criteria require more specimens. A verification test should be designed to judge the diagnostic power of the measurements.
Ellegård, Bertz, Winkvist, Bosaeus, & Brekke (2016) [**https://doi.org/10.1038/ejcn.2016.50**](https://doi.org/10.1038/ejcn.2016.50)	To evaluate if BIS or eight electrode multifrequency impedance (MFBIA) can estimate body composition expressed as fat mass (FM), fat-free	Study design: cross-sectional and longitudinal Intervention: BIS, MFBIA Outcomes: paired *t*-test and Bland Altman plots for systematic bias Evidence Level: III	72 lactating women who were overweight or obese were recruited for a randomized control trial for weight loss. This study reported body composition measurements at baseline, 12 weeks, and	BIS underestimates mean FM compared to DXA but can detect mean changes in body composition, with large agreement levels. BIS both accurately and precisely estimates muscle mass in overweight and obese women postpartum.	Feedback from measurements can help reinforce changes in diet and physical activity during therapy.	The number of MFBIA assessments were lower than BIS assessments, thus reducing the power to detect differences in MFBIA compared with DXA and DLW. BIS was measured in

Sweden	mass (FFM), and skeletal muscle mass (SMM). Comparing measurements to dual-energy x-ray absorptiometry (DXA) Also, BIS estimations will be validated against doubly labeled water (DLW).		one year. With this information, the writers of this study compared bioimpedance, DXA, MFBIA, and DLW	MFBIA underestimates FM and overestimates TBW by propriety equations compared with DXA and DLW.		supine, and MFBIA was measured in an upright position. Both per manufacturer instructions. Introduces systematic bias as the impedance will increase after 30 minutes in supine.
Hidding, Viehoff, Beurskens, Laarhoven, Nijhuis-Van Der Sanden, & Wees (2016) **https://doi.org/10.2522/ptj.20150412** **Netherlands**	Provide the best evidence regarding which measurement instruments are most appropriate for measuring lymphedema in its different stages.	Study design: Systematic Review Intervention: Pub Med and Web Science. PRISMA guidelines Outcomes: reliability, concurrent reliability, convergent validity, sensitivity, specificity, applicability. Evidence Level: I	631 studies were identified, of which 103 were eligible for full-text assessment. Of these studies, 51 were excluded due to inclusion criteria. Therefore 54 articles were assessed.	Measurements with evidence for good reliability and validity were BIS, volumetry, tape measurement, and perometry. BIS was able to detect changes in extracellular fluid in stage one lymphedema.	Impacts OT as prevention and early detection of lymphedema because early detection can lessen the burden of long-term care for the patient.	No uniform definition of lymphedema. No gold standard comparison test. Primary lymphedema measurements were poorly described.
Kenworthy, Grisbrook, Phillips, Gibson, Wood, & Edgar (2018) **https://doi.org/10.1016/j.burns.2017.06.007** **Australia**	This study aims to determine where alternate electrode placement was suitable for standardized positions in moderate to large size burns to measure BIS resistance and fluid changes.	Study design: longitudinal, prospective, single service study. Intervention: BIS measurements with no dressing or open wound and with new Acticoat dressing. Outcomes: Electrode placement included whole-body standard (WBS), whole-body alternative (WBA), upper limb standard (ULS), upper limb alternative	21 patients were recruited for this study. Patients were admitted with an acute burn requiring fluid resuscitation within 48 hours of injury.	Moderate to larger burn injuries clinicians can use whole body or upper limb segmental BIS variables to monitor fluid shifts with alternate electrode placements where wounds preclude standardized placement within specified dressing conditions.	Edema reduction in burn patients is imperative to counteract long term impairments that can result from major burns.	The study is limited for being generalized to clinical populations and older or younger subjects. Subjects were allowed to ingest water for 30 minutes before measurement, which could not have been distributed throughout the body.

		(ULA), lower limb standard (LLS), and lower limb alternative (LLA) Evidence Level: III				
Kenworthy, Grisbrook, Phillips, Gittings, Wood, Gibson, & Edgar (2017) https://doi.org/10.1016/j.burns.2017.04.022 **Australia**	To examine BIS's reliability and validity in the measurement of localized burn wound edema across different dressings and with three potential electrode placements. The BIS resistance was hypothesized to be inversely proportional to fluid volume.	Study design: longitudinal, prospective study Intervention: Outcomes: BIS measurements of wound edema across different dressings and three-electrode placements. Evidence Level: III	30 patients included in the study were over 18 y/o with a minor burn less than 5% total body surface area (TBSA) with the injury less than four days old and involved only the limbs. Patients with a BMI of 15-40 kg/m2.	Localized BIS is a reliable and non-invasive technique for assessing edema after minor burns with and without dressings in the area. BIS is more sensitive to edema volume changes compared to traditional edema measurement techniques. BIS can help limit the impact of poor outcomes associated with burn wound edema.	Edema contributes to wound progression, slows healing, and increases the risk of infection. Edema reduction and wound healing time are related to scar outcome. Edema reduction is integral in maximizing the patient's recovery.	Further investigation is needed to determine the effect of dressing age while using BIS.
Khalil, Mohktar, & Ibrahim (2014) https://doi.org/10.3390/s140610895 **Malaysia**	The purpose of this article is to review the main concepts of bioimpedance measurements. The paper also contributes to the deliberations of BIA assessment of abnormal loss in lean body mass and unbalanced shift in body fluids and the summary of diagnostic usage in cardiac, pulmonary, renal, neural, and infectious diseases.	Study design: Narrative report Intervention: none Outcomes: narrative review Evidence Level: V	Section one: main bioimpedance measurement approaches including single, multiple frequencies, broadband. Applied bioimpedance measurements across the whole body, through body segments and other alternative analysis Section two: body composition parameters, lean mass, and fluid volumes estimation. Section three: Basic factors, including anthropometric measurements, age, race,	There is a demand for accurate, cost-effective, and non-invasive systems for clinical status monitoring and diagnosis of diseases in healthcare. BIA is a growing method for body compartment estimations in nutrition studies, sports medicine, and evaluation rate of hydration rate, fat mass, and fat-free mass between healthy and unhealthy populations.	The use of bioimpedance analysis contributes to estimating body compartments to assess the regular change in nutrition in inpatients and to monitor nutritional risk in outpatients.	Further studies are needed to evaluate the correlations between variations in bioimpedance parameters and the relationship between health to disease.

			protocols, postures, shape, and electrode placement. <u>Section four</u>: bioimpedance applications in diagnosis prognosis and clinical monitoring.			
Khan, Y. H., Sarriff, Adnan, Khan, A. H., & Mallhi (2016) **https://doi.org/10.1007/s10157-016-1303-7** **Malaysia**	This study aimed to find the relationship between fluid overload and hypertension, along with prescribed diuretic therapy using BIS.	<u>Study design</u>: a prospective observational study <u>Intervention</u>: BIS measurements. <u>Outcomes</u>: absolute hydration (OH), intracellular water (ICW), extracellular water (ECW), and total body water (TBW) were calculated <u>Evidence Level</u>: III	312 chronic kidney disease (CKD) patients were enrolled in the study. Following overnight fasting, 5ml of blood was withdrawn to measure blood count. Estimated globular filtration rate (GFR) was calculated, and a renal function test was performed. BIS measurement was taken. The patient and the physicians were unaware of the fluid status measurements. Physicians prescribed diuretics via a hospital database.	BIS can help clinicians categorize CKD patients based on their fluid status and provide individualized pharmacotherapy to manage hypertensive CKD patients.	BIS has the potential to improve patient care by aiding in the assessment of fluid overload.	Fluid status was only measured once. The body composition monitor (BCM) had not been validated for CKD patients. Dietary intake and salt consumption were not recorded in this study.
Kuchnia, Yamada, Teigen, Krueger, Binkley, & Schoeller (2018) **https://doi.org/10.1007/s11657-018-0508-7**	The study aimed to determine if BIS derived estimates of body water components can be used in conjunction with dual-energy x-ray absorptiometry (DXA) measures to aid in predicting function and improving the	<u>Study design</u>: a cross-sectional study. <u>Intervention</u>: BIS and DXA measurements <u>Outcomes</u>: physical and muscle function test, jump mechanography, BIS measurements, and DXA scan completed. <u>Evidence Level</u>: III	112 ambulatory, cognitively intact men and women $\geq$ 70 years of age with the ability to stand without assistance and have no history of recent falls.	The study demonstrates that the best measure for explaining jump power was a new variable that combines DXA and body mass index corrected BIS measurements	Sarcopenia is an age-related loss of muscle mass and function which can impair function and quality of life. Early detection can improve quality of life and therapeutic interventions.	Narrow age range of older adults. A small sample of male subjects. Lifestyle, nutritional status, and physical activity status were not collected in this study. Other variables, such as

Madison, Wisconsin	diagnosis of sarcopenia.					central nervous system limitations, may impede function and strength.
Peppa, Stefanaki, Papaefstathiou, Boschiero, Dimitriadis, & Chrousos (2017) **https://doi.org/10.14310/horm.2002.1732** **Athens, Greece**	Aimed to evaluate the efficiency of a newly developed bioimpedance analysis (BIA-ACC) device as a screening tool for determining the degree of obesity and osteosarcopenia in post-menopausal women with normal or decreased bone density determined by DXA	Study design: a single gate reproducibility study Intervention: BIA-ACC and DXA measurements Outcomes: Height, weight, BMI, DXA derived indices, BIA derived indices, BIA-ACC measures Evidence Level: III	84 post-menopausal women aged 39-83 years. BMI ranging from 20.8 to 38. Among them, 22 females had a normal bone density, 38 were diagnosed with osteopenia, 24 with osteoporosis	BIA-CC is a rapid, bloodless, and useful screening tool for determining body composition, adiposity, and sarcopenic features in post-menopausal women.	The use of the BIA-ACC device offers clinicians a quick and easy way to expedite clinical decisions, thus improving patient outcomes and overall public health.	DXA scans underestimate fat-free mass. The researchers found intramuscular adipose tissue mass, suggesting muscular degeneration in the more obese participants. There was no psychometric questionnaire for stress, anxiety, or depression.
Pichonnaz, Bassin, Lécureux, Currat, & Jolles (2015) **https://doi.org/10.1186/s12891-015-0559-5** **Switzerland**	To explore the validity, reliability, and responsiveness of BIS for measuring edema after total knee arthroplasty (TKA).	Study design: a prospective validation study Intervention: Swelling was assessed following TKA using BIS, knee circumference, and volume measurements. Outcomes: BIS and volume measurements were taken the day before surgery, two days after surgery, and eight days after surgery. Limb volume was determined by using tape measurements at 4cm intervals using the truncated cone volume formula. Evidence Level: III	25 patients undergoing TKA were measured with BIS, knee circumferences, and limb volume.	BIS is an effective method for the evaluation of swelling following TKA.	BIS measurements can improve therapists' ability to reproduce measurements because it is straightforward and can be performed despite post-surgical dressings. Reduction in post-surgical swelling is imperative to improve patient outcomes and optimize recovery following TKA.	Gold standard validity was not tested. Comparison with advanced images could have provided more precise measurements, but advanced images would have been much more expensive.
Qin, Bowen,	To determine the	Study design: a	112 patients were	58 patients had positive	If there is suspicion of	Diagnostic accuracy of

& Chen (2018) **https://doi.org/10.1016/j.bjps.2018.02.012** **Iowa City, Iowa**	validity of BIS in diagnosing lymphedema by comparing results with indocyanine green (ICG) lymphography	retrospective cohort analysis Intervention: BIS measurements and ICG lymphography Outcomes: history and physical exam, lymphedema specific quality of life assessment (LYMQOL), circumference-based index, BIS, ICG lymphography Evidence Level: III	suspected, but 62 patients were included in the data analysis after the exclusion criteria.	ICG lymphography results confirming lymphedema, which these results also correlated with clinical exam, LYMQOL, and circumferential measurements. BIS demonstrated a 36% rate of false negative. 21 out of 58 patients had normal BIS readings, but positive ICG lymphography results.	lymphedema with a negative BIS result, further testing should be performed.	BIS using the data is limited due to the accuracy of the medical record. Patients seeking surgical management for lymphedema may have resulted in selection bias regarding patient demographics and disease severity. Also, precise electrode placement could have affected the result of the BIS assessment. Also, patient anatomy variances could affect the measurement.
Ridner, Dietrich, Cowher, Taback, McLaughlin, Ajkay, Boyages, Koelmeyer, DeSnyder, Wagner, Abranson, Moore, & Shah (2019) https://doi.org/10.1245/s10434-019-07344-5 **Nashville, TN**	To compare lymphedema progression rates using volume measurements calculated from tape measurements (TM) or BIS measurements.	Study design: a randomized controlled trial Intervention: BIS and TM. Patients received compression sleeves and gauntlets when lymphedema was noted to be triggered in either group. Outcomes: BIS vs. volume with TM. Evidence Level: I	508 newly diagnosed female patients participated in the study. Inclusion criteria: $\geq$18 y/o with a breast cancer diagnosis with planned surgery, stage I-III invasive cancer or ductal carcinoma in situ (DCIS) with mastectomy, axillary treatment, and taxane-based chemo. Randomized placement into BIS group and TM group. Measurements took place 3, 6, 12, 18, 24, 36 months	Interim results demonstrated that the post-treatment surveillance with BIS reduced the progression rates of breast cancer-related lymphedema (BCRL) requiring therapy by approximately 10%. The results support the post-surgical surveillance with BIS to detect BCRL and to initiate treatment.	Early detection of lymphedema can reduce the need for therapy and reduce the cost of long-term care for lymphedema patients.	The p-value was not met, which may be due to only 109 patients triggered early intervention, and only 12 of the 109 progressed to BCRL.
Seoane, Atefi, Tomner, Kostulas, Lindecrantz (2015) **Sweden**	The article presents clinical observations that suggest that stroke causes changes in cerebral BIS in the	Study design: observational study, cohort study Intervention: BIS measurements with 4 electrode placements.	Healthy population: Three male subjects between ages 29 – 59. Stroke population: 10 patients, five male, and	7 out of 10 in side-by-side group and 8 out of 10 in the central/lateral group comparisons present with values outside the normal range of the healthy	Time is an important factor when dealing with potential brain damage from stroke. Early detection and differentiating the	Small sample size.

https://doi.org/10.1155/2015/613247 **Sweden**	early phases of stroke onset.	Outcomes: BIS data analysis, symmetries, and differences. Side by side comparisons, central/lateral comparisons. Evidence Level: II	five females. Measurements obtained within the first 24 hours of stroke onset. Twenty consecutive measurements were recorded from each healthy and stroke patient, and the average was taken from each patient.	control group. Initial results indicate that BIS could be used as an emerging non-invasive monitoring technology for brain damage, leading to a paradigm shift in the treatment of brain damage and traumatic brain injury.	type of stroke is imperative in maximizing the patient's functional outcome.	
Seward, Skolny, Brunelle, Asdourian, Salama, Taghian (2016) **Boston,** **https://doi.org/10.1002/jso.24365** **Boston, MA**	To analyze the advantages, disadvantages, and results of studies utilizing BIS to establish an unbiased conclusion about BIS's evidence base as a clinical diagnostic tool for breast cancer-related lymphedema (BCRL).	Study design: Systematic review. Intervention: none Outcomes: Single frequency bioimpedance analysis (SFBIA), multiple frequency bioimpedance analysis (MFBIA), bioimpedance as a diagnostic tool for BCRL Evidence Level: I	The literary search began in July of 2015, including articles on BIS from 1992 to 2015. Literature included if it involved direct analysis of BIS as it relates to detection and diagnosis of BCRL.	Bioimpedance is an accurate diagnostic tool for pre-existent lymphedema, but at that time, it had not been validated for early detection.	Evidence-based practice is necessary for occupational therapy practice.	The studies do not provide long-term follow-up or clinical diagnosis to prove early detection or a false-positive result. Several studies had high rates of false negatives for BIS.
Tinsley, Graybeal, Moore, Nickerson (2018) **Texas,** https://doi.org/10.1249/mss.0000000000001749	The writers hypothesize that comparison to reference values would reveal that physique athletes possess lower density fat-free mass, mineral (DFFM) content of	Study design: a cohort study Intervention: DXA, BIS, SFBIA, MFBIAA, FFM was calculated, FFM Outcomes: total body water (TBW) estimates, FFM estimates, FFM characteristics. Evidence Level: II	26 athletes completed duplicate assessments of DXA, BIS, SFBIA, MFBIAA, FFM was calculated, FFM characteristics were determined. Measurements were compared between sexes and between sample and	The FFM characteristics differed between males and females.	Accurate assessment of body composition allows for appropriate treatment protocols and decision making on nutrition and exercise.	TBW assessments were not conducted using the true criterion method. Partial body DXA scans were used. The unique population of the study, the results should not be extrapolated

Texas	fat-free mass (FFM), and FFM protein content while exhibiting greater hydration.		reference values.			to the general population.
Ward, Czerniec, Kilbreath (2008) **https://doi.org/10.1007/s10549-008-0258-0** **Australia**	To calibrate impedance measurements of the arm to enable results to be reported in units of volume.	Study design: Cohort study Intervention: BIS measurements Outcomes: DXA measurements, arm length measurements, perometry, age, weight, height, BMI, limb dominance, Evidence Level: II	Two groups of women. Control group: 13 women with no history of lymphedema or breast cancer Second group: 23 clinically diagnosed with lymphedema from breast cancer.	BIS was not significantly different than that of perometry. BIS predicted that the increase in volume in women with lymphedema was predominantly due to increased extracellular fluid. BIS is capable of quantifying the volume increase in limb size seen in lymphedema.	Lymphedema is a chronic problem that can progress inevitably at a variable rate from person to person. Accurate assessment can improve treatment options and improve functional outcomes.	It was not possible to assess the absolute accuracy of the BIS derived fluid volumes. Perometer and BIS measurements do not assess the identical arm segments.
Ward, Dylke, Kilbreath (2012) **https://doi.org/10.1089/lrb.2012.0005** **Australia**	To demonstrate the feasibility of using BIS to assess hand volume, particularly extracellular fluid.	Study design: cohort study. Intervention: BIS measurements for volume Outcomes: age, weight, height, perometry measurements for hand volume. Evidence Level: II	20 males and 30 females were recruited from staff and students at the University of Sydney. All participants were right hand dominant. Impedances were measured, and volumes calculated. These were compared to volumes from perometry.	The region of the hand where volume was calculated was described as the palmar volume. The impedance measurements correlated with the perometry measurements but were on average 8% larger. The impedance technique was sensitive to changes in hand volume from positioning and elevation.	Hand volume is typically evaluated with Volumeter, but this method is time-consuming and has a larger associated margin of errors due to multiple steps required. Also, water displacement is not possible when wounds or dressings are present.	Uncertainties in the assumptions of calculations of volume from BIS measurements.

Appendix A: Syllabus

BIOIMPEDANCE FOR THE HEALTH CARE PROFESSIONAL

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Course Description: The purpose of the continuing education module is to educate health care professionals on the purpose and use of bioimpedance spectroscopy in the rehabilitation and wound care settings.
Course Credit: 1 CEU

Course Readings:

Khalil, S., Mohktar, M., & Ibrahim, F. (2014). The theory and fundamentals of bioimpedance analysis in clinical status monitoring and diagnosis of diseases. *Sensors*, *14*(6), 10895–10928. https://doi.org/10.3390/s140610895

Discussion Topics:

- Definition of BIS
- How it relates to Edema measurement
- BIS Measurements
- Discussion of appropriate Diagnoses
- Discussion of Contraindications
- Simulations
- Closing Statements

Schedule

- 5 minutes:
  - Introduction
  - Learning objectives
- 10 minutes:
  - Assessment tools
  - Video
- 10 minutes:
  - BIS measurements
- 10 minutes
  - What diagnoses are appropriate
  - Contraindications
- 20 minutes
  - Simulated Activity
  - Demonstration
- 5 minutes

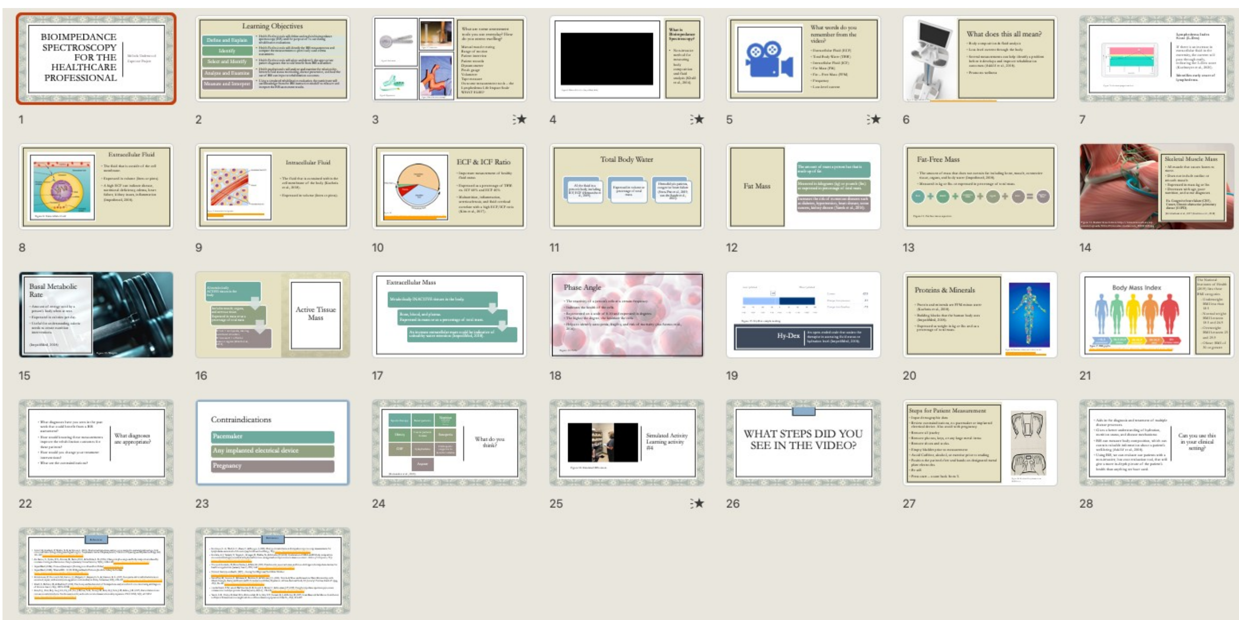
- Conclusion

Course Objectives:

Health Professionals will:

1. *Define* and *explain* bioimpedance spectroscopy (BIS) and the purpose of its use during rehabilitation evaluations.
2. *Identify* the BIS measurements and *compare* the measurements to previously used edema assessments.
3. *Select* and *identify* the appropriate patient diagnoses that would benefit from BIS assessment.
4. *Analyze* and *examine* the relationship between fluid status monitoring, disease prevention, and how the use of BIS can improve rehabilitation outcomes.
5. *Measure* and *interpret* the BIS assessment results using a simulated rehabilitation evaluation.

Presentation slide show:



https://liveutmb-my.sharepoint.com/:p:/r/personal/maunderw_utmb_edu/Documents/Bioimpedance%20Spectroscopy%20for%20the%20Health%20Care%20Professional/MUeducationmodule.pptx?d=wddef5f9323be4067ba69db2ca9e0f16c&csf=1&web=1&e=TTu6cb

Appendix B: Demonstration Check-Off Sheet

Hendrick Medical Center
Bioimpedance Spectroscopy for the Health Care Professional

1. Prepare the patient: Discuss contraindications, empty bladder, remove jewelry, cell phone, keys, shoes, and socks.

2. Confirm the tablet and device connection – perform Self-test.

3. Select patient or input new patient information.

4. Weigh the patient.

5. Educate the patient on the purpose of BIS measurements.

6. Dampen the patient's feet and hands with baby wipe.

7. Position the patient on the unit.

8. Perform the measurement.

9. Unit counts down 5 seconds before beginning the measurement.

10. Remind the patient to stand still.

11. Accept or reject the measurement and repeat if necessary.

12. After measurement is complete, assist the patient back to the chair.

13. Clean unit with 70% isopropyl alcohol wipes.

Appendix C: Lymphedema Treatment Intervention

An example of a preventative treatment intervention using the BIS is the Lymphedema Subclinical Lymphedema Surveillance Program. The program is appropriate for all patients with cancers associated with lymph node biopsy, trauma, or removal (Kilgore et al., 2018; Ridner et al., 2019; Shah et al., 2016). The stages of the program are:

Primary Prevention

- Baseline lymphedema measurement with BIS before cancer treatment.

Secondary Prevention

- Post-surgical lymphedema assessment every three months during the first three years.
- Post-surgical lymphedema assessment every six months during the fourth and fifth years.
- Post-surgical lymphedema assessment annually after six years.

Tertiary Prevention

- During the testing procedures, if the L-Dex score shows an increase of 6.5 over the baseline score, this indicates the presence of subclinical lymphedema, which would require the initiation of the lymphedema treatment program (Kilgore et al., 2018; Ridner et al., 2019; Shah et al., 2016). The lymphedema treatment program includes compression garment wear for twelve hours per day and patient-directed self-massage for four to six weeks (Kilgore et al., 2018; Ridner et al., 2019). Ridner et al. (2019) report that subclinical lymphedema surveillance with BIS reduced the incidence of breast cancer-related lymphedema requiring advanced lymphedema treatment.

Appendix D: Lymphedema Clinical Case Example

46 y/o female referred to the lymphedema clinic with a breast cancer diagnosis. Patient seen for pre-surgical consult and follow-up screens for lymphedema. The patient participated in the primary, secondary, and tertiary prevention programs with the lymphedema treatment protocol.

L-DEX Baseline: -5.9 L-DEX Trigger: 1.0 (increase 6.9) L-DEX post treatment: -7.4

Fluid Analysis

Total Body Water (TBW): 38.8 liters	50.3 % of weight
Extracellular Fluid: 17.4 liters	44.8 % of TBW **(low)**
Intracellular Fluid: 21.4 liters **(high)**	55.2 % of TBW **(high)**

Tissue Analysis

Fat Free Mass: 116.8 lbs.	68.7 % of weight
Fat Mass: 53.2 lbs.	31.3 % of weight
Skeletal Muscle Mass: 48.8 lbs.	28.7 % of weight

Weight

Total Body Water: 38.8 liters	50.3 % of weight
Proteins & Minerals: 31.3 lbs.	18.4 % of weight
Fat Mass: 53.2 lbs.	31.3 % of weight

Other

Basal Metabolic Rate	1448.7 calories/day
Phase Angle	4.9 ° **(6.8 to 8.4)**
Body Mass Index	26.6 kg/m^2
Weight	170.0 lbs.

Hy-dex Analysis 14.2

Appendix E: Sarcopenia Treatment Intervention

Sarcopenia is the loss of muscle mass, which negatively impacts finances, mobility, function, quality of life, and mortality (Kuchnia et al., 2018). The elderly population will increase to three times what it is today; thus, sarcopenia is a significant health concern for the aging population (Kuchnia et al., 2018). Evaluation tools to aid in diagnosing sarcopenia are limited; therefore, it is imperative to identify the appropriate tools to measure muscle function and monitor therapy treatments (Kuchnia et al., 2018). A detailed evaluation of body composition, including fat, skeletal muscle mass, phase angle, and hydration, can help identify sarcopenia and osteopenia/osteoporosis (dos Santos et al., 2016; Peppa et al., 2017).

Muscle quality describes changes to age-related decline in muscle mass and function; therefore, it is essential to assess muscle quality and muscle mass when identifying sarcopenia (Kuchnia et al., 2018). Tools used to assess muscle mass include "computed tomography (CT), magnetic resonance (MR), dual-energy X-ray absorptiometry (DXA), and bioimpedance" (Kuchnia et al., 2018, p. 2). Fluid distribution is one method to assess muscle quality, specifically the ratio between extracellular fluid (ECF) and intracellular fluid (ICF) (Kuchnia et al., 2018).

A study by dos Santos et al. (2016) discussed using phase angle (PhA) to predict sarcopenia and muscle function. Body composition, hydration, and PhA are predictors of the average aging process (dos Santos et al., 2016). Through resistance training with older women, PhA increased, resulting in improved cellular health; conversely, the absence of resistance training resulted in a decrease in PhA (dos Santos et al., 2016).

Peppa et al. (2017) compared the DXA machine with bioimpedance analysis to evaluate obesity and osteosarcopenia in post-menopausal women. The researchers used a bioimpedance device to measure fat mass, skeletal muscle mass (SMM), and fat-free mass (FFM) (Peppa et al., 2017). The study results found higher SMM and FFM in non-osteopenic women compared to the osteopenic group (Peppa et al., 2017). Therefore, bioimpedance is a useful tool in identifying obesity, declines in SMM, and FFM (Peppa et al., 2017). Bioimpedance devices are rapid and non-invasive screening tools that do not require radiation as in the DXA assessments (Peppa et al., 2017).

The review of the literature indicates that BIS monitoring is beneficial for the early identification of sarcopenia. Therefore, monitoring the following criteria will aid in the overall care of the aging population.

- **SMM**: all the muscle that causes the bone to move; does not include cardiac or smooth muscle
- **FM**: the amount of mass a person has made up of fat.
- **FFM**: The amount of mass that does not contain fat, including bone, muscle, connective tissue, organs, and body water (Impedimed, 2018).
- **PhA**: the reactivity of a person's cells at a specific frequency; indicates the health of the cell. The higher the degree, the healthier the cell.
- **ECF/ICF ratio**: Ratio between ECF and ICF. Higher ratios indicate low muscle quality.

Appendix F: Sarcopenia Clinical Case Example

56 y/o female referred to the lymphedema clinic with right breast cancer. Patient with severe right upper extremity lymphedema and significant weight loss.

L-DEX score initial score: 44.7 **(out of normal limits)**

One-month later analysis: 102.1 **(out of normal limits)**

Fluid Analysis

Total Body Water (TBW): 33.8 liters	70.0 % of weight **(high)**
Extracellular Fluid: 16.5 liters	48.8 % of TBW
Intracellular Fluid: 17.3 liters	51.2 % of TBW

Tissue Analysis

Fat Free Mass: 101.7 lbs.	95.4 % of weight **(high)**
Fat Mass: 4.7 lbs. **(low)**	4.6 % of weight **(low)**
Skeletal Muscle Mass: 51.2 lbs.	48.0 % of wt.

Weight

Total Body Water: 33.8 liters	70.0 % of weight
Proteins & Minerals: 27.2 lbs.	25.4 % of weight
Fat Mass: 4.7 lbs.	4.6 % of weight

Other

Basal Metabolic Rate	1105.2 calories/day (Low)
Phase Angle	2.5 ° **(low)**
Body Mass Index	16.7 kg/m²
Weight	106.4 lbs. **(low)**
Hy-dex Analysis	52.1

Appendix G: Congestive Heart Failure Treatment Intervention

Congestive heart failure (CHF) is a chronic condition where the heart has decreased ability to pump fluids through the body (Weyer et al., 2014). There is a substantial impact on the occupational performance of those persons affected by CHF (Norberg et al., 2014). Lower extremity edema, shortness of breath, fatigue are a few physical symptoms that impede a person's independent living (Norberg et al., 2014). In addition to physical symptoms, there are distressing symptoms such as feelings of hopelessness and powerlessness because of role changes (Norberg et al., 2014).

Patients with CHF experience frequent hospitalizations due to fluid accumulations (Weyer et al., 2014). CHF treatment will be a challenge for health care companies and payers due to the large aging population (Accardi et al., 2019). Physical signs and symptoms are low indicators of cardiac decompensation or the possible need for medication management (Weyer et al., 2014). Early detection of decompensation may reduce mortality and the number of hospitalizations, therefore reducing health care costs (Weyer et al., 2014). Many tools exist to detect fluid accumulation, but there is a need for a non-invasive method for recognizing cardiac decompensation (Weyer et al., 2014). Bioimpedance spectroscopy (BIS) is a tool used to measure fluid volume and extracellular fluid (Accardi et al., 2019; Weyer et al., 2014). Using BIS trends to monitor total body water and extracellular fluid, therapists can monitor fluid imbalances more accurately (Accardi et al., 2019). A study by Accardi et al. (2019) compared the use of BIS to measurements with echocardiographic parameters to assess fluid overload. The study results indicate that BIS measurements correlate with echocardiographic parameters indicating that BIS is a possible tool to detect fluid overload (Accardi et al., 2019).

The review of the literature indicates that BIS monitoring is beneficial for the early identification of cardiac decompensation. Therefore, monitoring the following criteria will aid in the overall care of the CHF patient.

- **Total Body Water (TBW):** All the fluid in a person's body, including ECF and ICF.
- **ECF**: The fluid outside the cell membrane.

Appendix H: Congestive Heart Failure Clinical Case Example (still need to measure)

70 y/o male referred to the wound care clinic for evaluation of lower extremity edema. Past medical history includes: CHF, coronary artery disease, thoracic aortic aneurysm.

Bioimpedance Spectroscopy Screening

Fluid Analysis

Total Body Water (TBW): 61.5 liters **(high)**	49.3% of weight **(low)**
Extracellular Fluid: 29.4 liters **(high)**	47.8% of TBW **(low)**
Intracellular Fluid: 32.1 liters **(high)**	52.2% of TBW **(low)**

Tissue Analysis

Fat Free Mass: 185.2 lbs. **(high)**	67.4% of weight **(low)**
Fat Mass: 89.8 lbs. **(high)**	32.6% of weight **(high)**
Skeletal Muscle Mass: 79.8 lbs.	29.0% of weight

Weight

Total Body Water: 61.5 liters	49.3% of weight
Proteins & Minerals: 49.6 lbs.	18.1% of weight
Fat Mass: 89.8 lbs.	32.6% of weight

Other

Basal Metabolic Rate	2029.5 calories/day
Phase Angle	4.6 ° **(low)**
Body Mass Index	38.4 kg/m² **(high)**
Weight	275 lbs. **(high)**
Hy-dex Analysis	14.2

Appendix I: Chronic Kidney Disease Treatment Intervention

There is a growing number of chronic diseases with the aging population, including chronic kidney disease (CKD). In various CKD stages, patients experience caloric metabolism changes, which decreases muscle mass and fat mass (Arias-Guillén et al., 2018). Also, patients with CKD experience fluid overload resulting in increased hypertension in hemodialysis patients (Khan et al., 2019). Fluid overload is associated with increased cardiovascular risk and increased mortality among CKD patients (Khan et al., 2019). Monitoring fluid status is vital for CKD undergoing hemodialysis (HD) due to the absence of renal function (van der Sande et al., 2019). Patients undergoing HD can experience extreme differences between fluid overload and fluid decreases (van der Sande et al., 2019). Fluid overload leads to hypertension, while fluid depletion can lead to hypotension, tissue ischemia, and potential loss of residual renal function (van der Sande et al., 2019).

Chronic diseases associated with malnutrition can lead to poor outcomes (Han et al., 2018). Low albumin levels can be related to malnutrition and are connected to increased mortality rates (Han et al., 2018). In addition to fluid overload, fluid depletion, and hypoalbuminemia, PhA has been used to assess nutrition with several other chronic conditions, including CKD (Han et al., 2018).

Many tools exist to measure fluid status for CKD patients, including clinical examination, which is inaccurate and does not provide all the details to the patient's health (van der Sande et al., 2019). Because of the delicate factors associated with the CKD patient's health, there is a need for a non-invasive, accurate tool that can assess TBW, ECF, ICF, PhA, and protein levels.

The literature review indicates that BIS monitoring is beneficial in fluid overload and body composition monitoring for the CKD patient. Therefore, monitoring the following criteria will aid in the overall care of the CKD patient.

- **TBW**: All the fluid in a person's body, including ECF and ICF.
- **ECF**: The fluid outside the cell
- **ICF**: The fluid inside the cell wall.
- **PhA**: the reactivity of a person's cells at a specific frequency; indicates the health of the cell. The higher the degree, the healthier the cell.
- **Protein**: Building blocks of the human body. Low protein levels can be associated with malnutrition.

Appendix J: Chronic Kidney Disease Clinical Case Example

62 y/o female referred to the wound care clinic following wound abscess with irrigation and debridement to the left buttock. Past medical history includes: diabetes mellitus, hypertension, and stage IV kidney disease.

Bioimpedance Spectroscopy Screening

Fluid Analysis	
Total Body Water (TBW): 36.0 liters	40.5% of weight **(low)**
Extracellular Fluid: 17.7 liters	49.3% of TBW **(low)**
Intracellular Fluid: 18.3 liters	50.7% of TBW
Tissue Analysis	
Fat Free Mass: 108.5 lbs.	55.3% of weight
Fat Mass: 87.5 lbs.	44.7% of weight
Skeletal Muscle Mass: 42 lbs.	21.4% of weight
Weight	
Total Body Water: 36 liters	40.5% of weight
Proteins & Minerals: 29.1 lbs.	14.8 % of weight
Fat Mass: 87.5 lbs.	44.7% of weight
Other	
Basal Metabolic Rate	1402.3 calories/day
Phase Angle	3.1 ° **(low)**
Body Mass Index	35.8 kg/m² **(high)**
Weight	196.0 lbs. **(high)**
Hy-dex Analysis	8.0

Appendix K: Wound Care Clinical Case Example

53 y/o male referred to the wound care clinic following an injury where the patient received burns to the left calf and abdomen. Past medical history includes: Hepatitis C, Cirrhosis of the liver, vision impairment, and diverticulitis.

Bioimpedance Spectroscopy Screening

Fluid Analysis

Total Body Water (TBW): 57.4 liters **(high)**	53.6 % of weight
Extracellular Fluid: 26.9 liters **(high)**	46.9 % of TBW **(high)**
Intracellular Fluid: 30.5 liters **(high)**	53.1 % of TBW **(low)**

Tissue Analysis

Fat Free Mass: 172.9 lbs. **(high)**	73.3 % of weight
Fat Mass: 63.1 lbs.	26.7 % of weight
Skeletal Muscle Mass: 79.3 lbs.	33.6 % of weight

Weight

Total Body Water: 57.4 liters	53.6 % of weight
Proteins & Minerals: 46.3 lbs.	19.7 % of weight
Fat Mass: 63.1 lbs.	26.7 % of weight

Other

Basal Metabolic Rate	1858.2 calories/day
Phase Angle	5.7 ° **(low)**
Body Mass Index	38.1 kg/m^2 **(high)**
Weight	236.0 lbs. **(high)**
Hy-dex Analysis	13.1

Appendix L: Pre/post test

1. Bioimpedance Spectroscopy (BIS) is:
   a. A tool to detect late-stage lymphedema
   b. A device that can monitor trunk girth and monitor circumference of the waist.
   c. is a method for monitoring body fluid fluctuations, body composition, nutrition status, and hydration rate.
   d. Special electrical current that can be used with any patient.
   e. A tool that uses an electrical current to measure a patient's heart rhythm.

2. Edema is most commonly measured by using:
   a. Volumeter
   b. Perometer
   c. Tape measurement
   d. Weight
   e. Visual inspection

3. Early detection of lymphedema
   a. Can be done with visual aid education.
   b. Is appropriate only for breast cancer patients.
   c. Can reduce the onset of clinical lymphedema, which will decrease health care costs.
   d. Occurs only in the first 6 months.
   e. Happens only for patients with node dissection

4. How does SOZO BIS work?
   a. By using 2-6 different frequencies to measure the resistance of the current and body fluids.
   b. By weighing the patient and converting this to Body Mass Index and Fat mass variables.
   c. A painless current is passed through the body and measures the body's resistance and reactance to the current.
   d. The unit measures the impedance at 246 different frequencies to measure weight, BMI, and body composition.
   e. C & D

5. Knowledge of total body water for therapy patients is important to:
   a. Help monitor fluid burden for heart failure patients
   b. Facilitate mobility following surgery.
   c. Determine if deep breathing exercises are effective for lymphatic movement.
   d. Monitor the patient's risk of diabetic ulcer
   e. All of the above

6. BIS can measure skeletal muscle mass to help detect
   a. Sarcopenia
   b. Critically ill patient mortality
   c. Weight loss

   d. Kidney Dysfunction
   e. Heart Failure

7. The use of BIS monitoring can help to promote?
   a. Diet
   b. Exercise
   c. Wellness
   d. Heart health
   e. Cancer detection

8. What information is needed prior to measuring a patient with the BIS unit?
   a. Work history
   b. Stage of Lymphedema
   c. BMI
   d. Waist circumference
   e. Extremity dominance

9. Phase angle is
   a. An indicator of cellular health and integrity.
   b. High, which represents the cell's inability to store energy.
   c. Represents the ratio between body cell mass and fat mass.
   d. Low, which represents a large quantity of intact cell membranes and body cell mass.
   e. Represented by a range between 1 to 30 degrees.

10. Which diagnoses does NOT benefit from BIS measurement?
   a. Congestive heart failure
   b. Sarcopenia
   c. Kidney Failure
   d. Cancer
   e. Lymphostatic Elephantiasis

Appendix M: COURSE EVALUATION FORM

Bioimpedance Spectroscopy for the Health Care Professional

1. How likely is it that you would recommend this session to a friend or colleague?

NOT AT ALL LIKELY EXTREMELY LIKELY

1	2	3	4	5	6	7	8	9	10

2. How relevant is the material to your role?

- o Extremely relevant
- o Very relevant
- o Somewhat relevant
- o No so relevant
- o Not at all relevant

3. How clear was the presentation of information?

- o Extremely clear
- o Very clear
- o Somewhat clear
- o Not so clear
- o Not at all clear

4. How do you feel about the amount of information presented?

- o Much too little information
- o Somewhat too little information
- o About the right amount of information
- o Somewhat too much information
- o Much too much information

5. How engaging was your instructor?

- Extremely engaging
- Very engaging
- Somewhat engaging
- Not so engaging
- Not at all engaging

6. How would you rate your instructor's knowledge of the material?

- Excellent
- Very good
- Good
- Fair
- Poor

7. How clear are you on the takeaways from the session?

- Extremely clear
- Very clear
- Somewhat clear
- Not so clear
- Not at all clear

8. Do you have any other comments, questions, or concerns?

Appendix N: System Usability Scale (SUS)

For each of the following statements, please mark one box that best describes your reactions to Bioimpedance Spectroscopy today. 1 = strongly disagree, 5 = strongly agree

1. **I think that I would like to use Bioimpedance Spectroscopy frequently.**

1	2	3	4	5

2. **I found Bioimpedance Spectroscopy unnecessarily complex.**

1	2	3	4	5

3. **I thought Bioimpedance Spectroscopy was easy to use.**

1	2	3	4	5

4. **I think that I would need the support of a technical person to be able to use Bioimpedance Spectroscopy.**

1	2	3	4	5

5. **I found the various functions in Bioimpedance Spectroscopy were well integrated.**

1	2	3	4	5

6. **I thought there was too much inconsistency in Bioimpedance Spectroscopy.**

1	2	3	4	5

7. **I would imagine that most people would learn to use Bioimpedance Spectroscopy very quickly.**

1	2	3	4	5

8. **I found Bioimpedance Spectroscopy very cumbersome (awkward) to use.**

1	2	3	4	5

9. **I felt very confident using Bioimpedance Spectroscopy.**

1	2	3	4	5

10. **I needed to learn a lot of things before I could get going with Bioimpedance Spectroscopy.**

1	2	3	4	5

Table 3: Statistical Analysis

System Usability Scale (SUS)	83.8
Learnability	84.4
Usability	83.6
Standard deviation	11.6
Cronbach's alpha	0.855

Table 4: Clinical Utility Survey Results

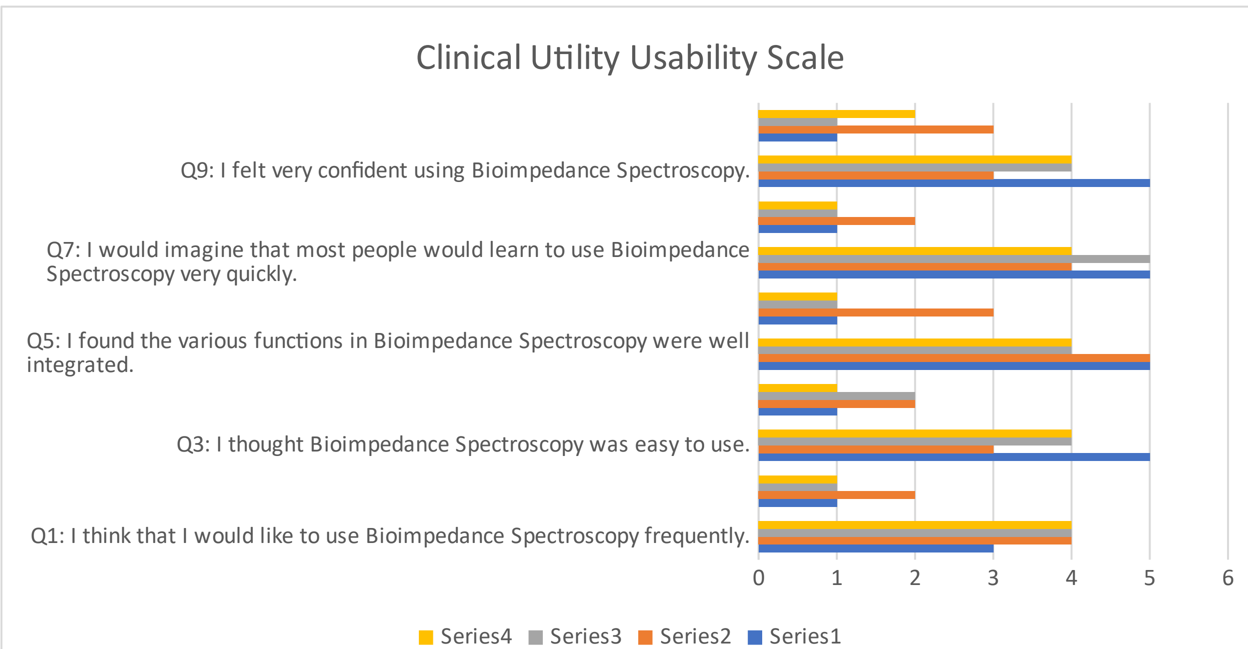
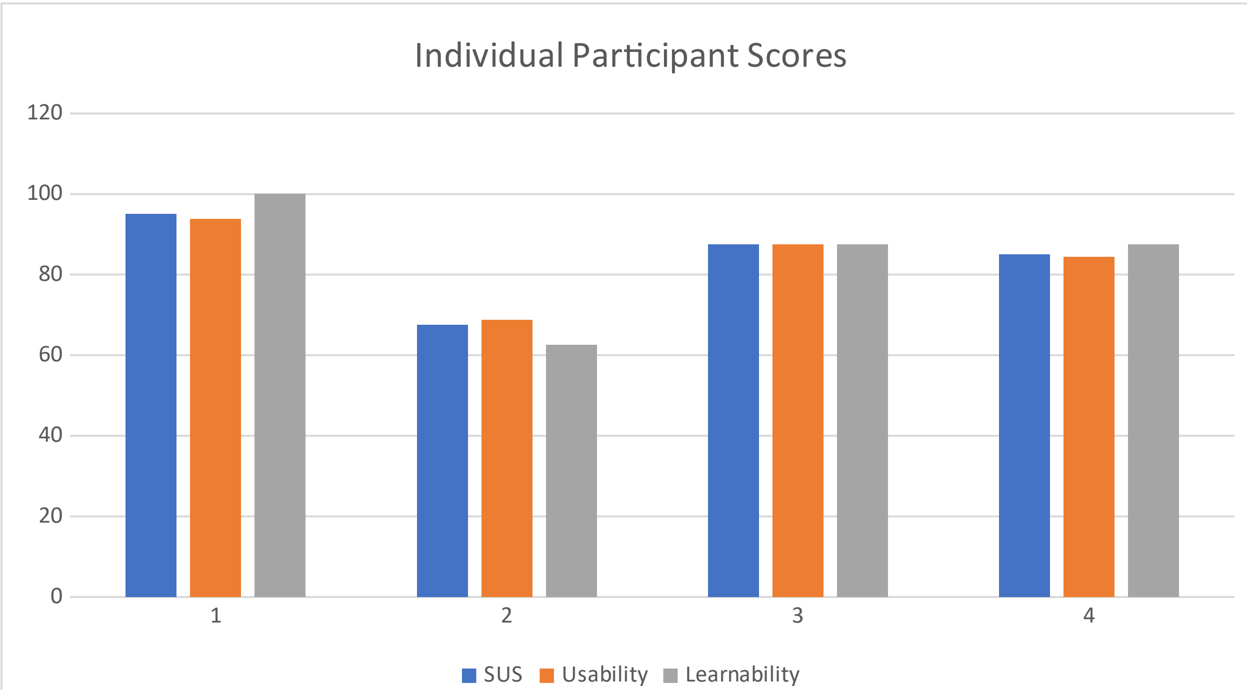


Table 5: Individual Participant Scores



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Appendix O: Interview Questions

Debriefing questions with the Wound care Team for a one-month clinical utility survey: Planned for 10/13/2020. Formal write up of this section to follow.

1. Were you able to use the BIS unit for patient evaluations?
2. If so, how did you incorporate that information into your patients' goals or interventions?
3. Describe what insights you gained into the health of your patient through the use of the BIS measurements.
4. How did you alter your treatment interventions through the use of the BIS measurement data?
5. What are the patient diagnoses that you have seen that would benefit from the BIS device?
6. If you were not able to use the unit, what barriers prevented you from using the device?
7. What could the department do to help facilitate the usability of the BIS device?
8. How can we make the BIS more user friendly and applicable to your patient population?
9. As a staff member, is there anything you can do to encourage others to participate in BIS measurements?
10. What is the most significant value that the BIS device adds to the department?

Table 6: Interview Question Answers

QUESTIONS	**PARTICIPANT #1**	**PARTICIPANT #2**	**PARTICIPANT #3**	**PARTICIPANT #4**
1. Were you able to use the BIS unit for patient evaluations?	**NO**	**NO**	**NO**	**NO**
2. If so, how did you incorporate that information into your patients' goals or interventions?	**NA**	**NA**	**NA**	**NA**
3. Describe what insights you gained into the health of your patient through the use of the BIS measurements	**NA**	**NA**	**NA**	**NA**
4. How did you alter your treatment interventions through the use of the BIS measurement data?	**NA**	**NA**	**NA**	**NA**

5. What are the patient diagnoses that you have seen that would benefit from the BIS device?	**Venous stasis ulcers, Peripheral vascular disease, post-operative wound surgeries**	**Patients with Diabetic Foot Ulcers, Venous Stasis Ulcers, and Lymphedema**	**Kidney Failure, Congestive Heart Failure**	**Lymphedema patients, venous stasis ulcer patients, diabetic ulcer patients**
6. If you were not able to use the unit, what barriers prevented you from using the device?	**Need time to set up in Apollo, time to test, most people have gross feet**	**There are no barriers**	**low staffing causing patient backlogging, infection control, wound vac, mobility, location, feet are wrapped**	**Location, mobility, patients cannot walk to small room without dressings on feet and legs, drainage from leg wounds.**
7. What could the department do to help facilitate the usability of the BIS device?	**Out of sight, out of mind. If it were front and center or we discussed it regularly, it would be in the forefront of my mind to use it.**	**I can do a better job of reminding staff that it is available to use on new patient evals.**	**Change the location of the unit.**	**Just be more vigilant on who to use the device on and be more proactive in its use.**
8. How can we make the BIS more user friendly and applicable to your patient population?	**Unknown**	**I'm not sure. It seems very user and patient friendly.**	**NA**	**unsure yet, will know more with use of the device**
9. As a staff member, is there anything you can do to encourage others to participate in BIS measurements?	**Perhaps if there was a reward program or incentive to patients.**	**As stated above, make sure the staff remembers that it is available to use.**	**NA**	**NA**
10. What is the most significant value that the BIS device adds to the department?	**It's shiny and new and looks cool.**	**I think we need to use it to actually identify its value**	**Unsure at this time**	**NA**

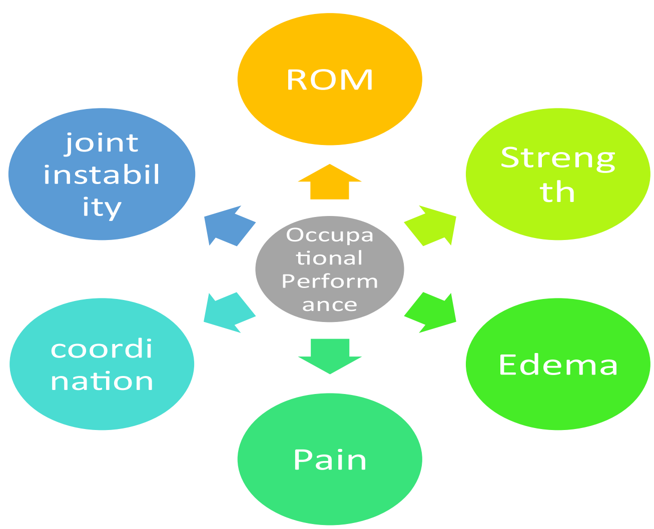
Appendix P: Theoretical Frame of Reference

BIOMECHANICAL FRAME OF REFERENCE

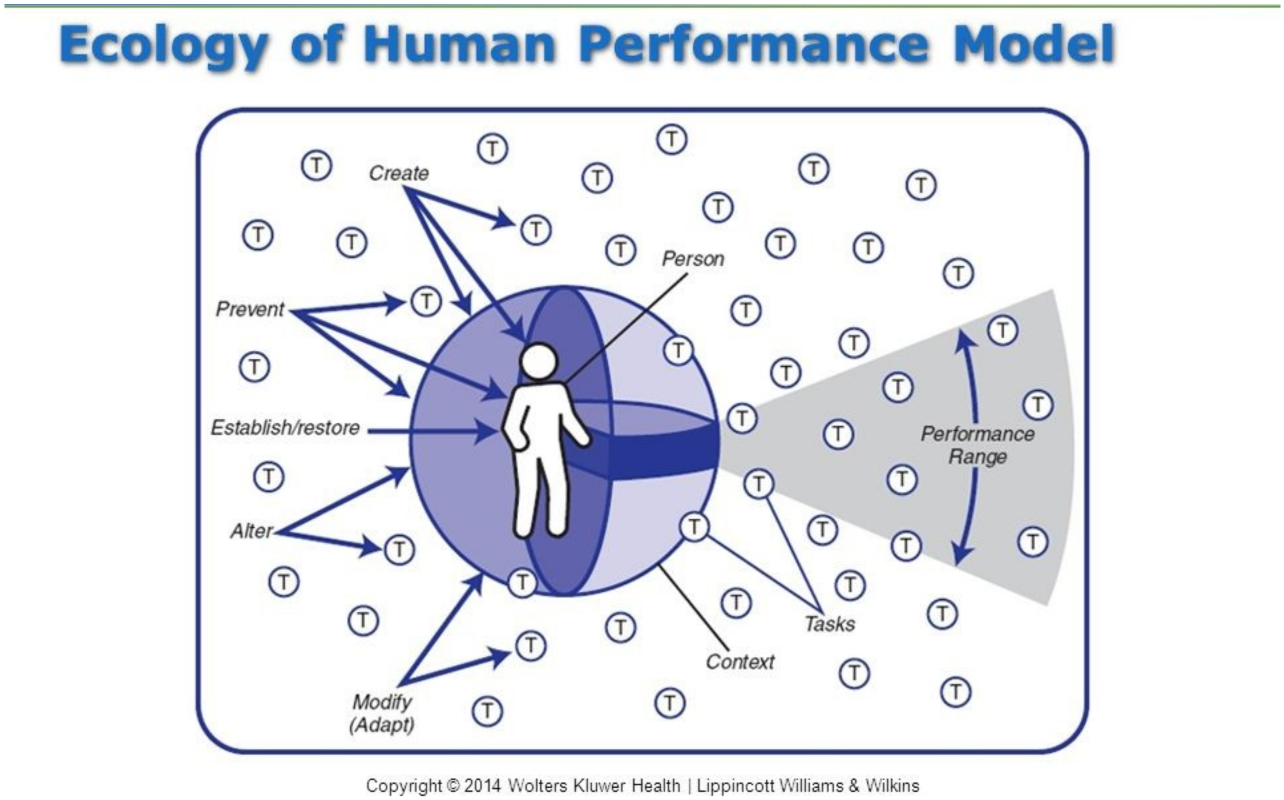
The Biomechanical Frame of Reference (FoR) applies to the principles of physics and the biomechanics of movement of the human body (Cole & Tufano, 2020). The principles of this FoR are considered a remediation approach because impairments noted in this area limit the individual's occupational performance (Gillen & Nilsen, 2019). Examples of impairments focused on with this FoR are range of motion, edema, pain, weakness, strength, coordination, and joint instability (Gillen & Nilsen, 2019). The Biomechanical FoR guides the assessment where therapists choose appropriate evaluation tools to form the baseline of occupational performance.

The assumptions of this model (Gillen & Nilsen, 2019)

1. Remediation can aid the impairment
2. Participating in occupations is a tool to help remediate disability
3. Improving the disability through the use of occupations will improve occupational performance.



Appendix Q: Theoretical Model



The theoretical model guiding the project is one described by Dr. Winnie Dunn, and her colleagues called the Ecology of Human Performance (EHP) model (Dunn et al., 1994). The EHP model's focus is wellness and health promotion, which aligns with the goal of this project. EHP is a model used for all persons regardless of age or time of life and can be used by other disciplines, educators, and occupational therapists. EHP is used in various settings to include outpatient therapy settings and wellness programs because it emphasizes a preventative and health promotion attitude (Cole & Tufano, 2008). The EHP model explains the relationship between the person, their environment, and the tasks performed in the environment (Turpin & Iwama, 2011). Through the lens of the EHP model, the occupational therapist can use the BIS unit to help prevent diseases, create programs to support wellness, and encourage health promotion purposes for all stages of life (Qin et al., 2017).

EHP was designed to be used by other disciplines, educators, and occupational therapists (Cole & Tufano, 2008). Also, EHP can be used in a variety of settings to include outpatient therapy settings and wellness programs (Cole & Tufano, 2008). According to Cole and Tufano (2008), "the model emphasizes a preventative, health promotional, and rehabilitative attitude" (p.117). The EHP model outlines five intervention areas to meet the needs of the person in their environment (Turpin & Iwama, 2011). These intervention categories include create, establish, maintain, modify, and prevent (Turpin & Iwama, 2011). Through the participation in this continuing education module, the participant will learn how to utilize the BIS unit and gain insight into the patient's health. The continuing education module's goal is to understand how health professionals can provide appropriate interventions to identify and prevent exacerbations of diseases and promote overall health and wellness.

Table 7: BIS measurement and associated diagnosis

Diagnosis	Associated BIS Measurement
Lymphedema	L-DEX (Lymphedema Index)
Sarcopenia	Skeletal Muscle Mass, Phase Angle, Fat Mass, Fat Free Mass
Cachexia	Skeletal Muscle Mass, Fat Mass, Phase Angle
Congestive Heart Failure	Extracellular Fluid, Intracellular fluid, Total Body Water
Renal Failure	Extracellular Fluid, Intracellular fluid, Phase Angle, Total Body Water, Protein
Eating Disorders	Fat Mass, Fat Free Mass, Total Body Water, Extracellular Fluid & Intracellular Fluid ratio
Exercise Training Programs	Fat Mass, Skeletal Muscle Mass
Oncology	Total Body Water

Table 8: Norm data for BIS measurements

Female Reference Ranges (1 standard deviation from mean)

N	1448	1511	1632	1248	907	1031	817	477	44
Age	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
Weight (lb)	98.2 to 164.2	110.8 to 180.8	118.1 to 203.7	125.4 to 203.8	126.7 to 205.7	123.5 to 192.5	118 to 182.8	110.4 to 162	100.1 to 136.7
Phase Angle	6.7 to 8.3	7 to 8.6	6.8 to 8.6	6.8 to 8.4	6.2 to 8	5.8 to 7.6	5.2 to 7.2	4.7 to 6.5	4.3 to 5.7
TBW (liters)	25.5 to 34.5	26.9 to 36.5	28.1 to 39.1	28.4 to 39.2	28.4 to 39.2	27.6 to 37.4	26.9 to 36.7	25.7 to 33.9	24.5 to 31.5
TBW (%)	45.3 to 57.9	43.2 to 54.8	41.2 to 53.4	41.1 to 51.3	40.6 to 51	41.2 to 51	42.1 to 52.7	43.7 to 54.1	46.8 to 58.4
ICF (liters)	14.5 to 18.3	15.1 to 19.1	15.6 to 20.2	15.7 to 20.1	15.6 to 20	15 to 19.2	14.7 to 18.7	14 to 17.4	13.3 to 16.3
ICF (% of TBW)	52.8 to 57	52.4 to 56.2	51.5 to 55.5	51.3 to 55.1	50.8 to 54.8	50.9 to 54.9	50.7 to 54.7	50.9 to 54.9	50.9 to 55.1
ECF (liters)	10.9 to 16.3	11.8 to 17.4	12.4 to 19	12.7 to 19.1	12.9 to 19.3	12.5 to 18.3	12.2 to 18	11.6 to 16.6	11.1 to 15.3
ECF (% of TBW)	43 to 47.2	43.8 to 47.6	44.5 to 48.5	44.9 to 48.7	45.2 to 49.2	45.1 to 49.1	45.3 to 49.3	45.1 to 49.1	44.9 to 49.1
Fat Mass (lb)	20.4 to 64.2	28.2 to 75.4	32.8 to 90.4	38.8 to 90.4	40.3 to 92.3	39.6 to 84.8	35.8 to 78	31.9 to 65.9	23.1 to 50.1
Fat Mass (%)	22.4 to 38.8	26.4 to 41.8	28.6 to 44.6	31.2 to 44.8	31.6 to 45.6	31.7 to 44.9	29.9 to 43.7	28.1 to 41.9	22.7 to 37.5
Fat Free Mass (lb)	75.6 to 102.2	80.1 to 107.9	83 to 115.8	84.3 to 115.9	84.2 to 115.6	81.5 to 110.1	79.3 to 107.5	75.5 to 99.1	72.6 to 91
Fat Free Mass (%)	61.2 to 77.6	58.2 to 73.6	55.4 to 71.4	55.2 to 68.8	54.4 to 68.4	55.1 to 68.3	56.3 to 70.1	58.1 to 71.9	62.5 to 77.3
BMR (cal)	1296.3 to 1591.1	1308.7 to 1621.9	1295 to 1674.4	1282.5 to 1631.5	1236.8 to 1589	1172 to 1482	1098.4 to 1393.2	1018.3 to 1255.9	941 to 1106.8
BMI	17.8 to 28.2	19.5 to 31.1	20.7 to 35.1	22 to 35.2	22.5 to 35.7	22.5 to 34.3	22 to 33	21.2 to 30.2	19.3 to 26.3

Male Reference Ranges (1standard deviation from mean)

N	1379	1553	1383	1155	792	1055	724	474	32
Age	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
Weight (lb)	104.1 to 179.5	132.6 to 208.6	142.4 to 217.6	147.6 to 221.2	149.5 to 221.5	147.1 to 213.3	139.7 to 202.1	133.1 to 187.1	116.8 to 170.2
Phase Angle	7 to 9	7.8 to 9.6	7.6 to 9.4	7.2 to 9.2	6.7 to 8.5	6.2 to 8	5.4 to 7.4	4.8 to 6.6	4.2 to 6.6
TBW (liters)	30 to 46.2	36.3 to 50.9	37.9 to 52.9	38.6 to 53.4	38.8 to 53.4	37.6 to 51.6	36.2 to 49.6	34.6 to 46.6	31.5 to 43.5
TBW (%)	54.3 to 66.1	52 to 62.2	51.4 to 61	50.9 to 60.1	50.7 to 59.9	50.4 to 59.6	51.1 to 60.3	51.5 to 61.3	52.1 to 64.1
ICF (liters)	18.8 to 27	22.1 to 29.5	22.9 to 30.5	23.2 to 30.6	23.2 to 30.4	22.4 to 29.4	21.4 to 28	20.4 to 26.2	18.6 to 24.6
ICF (% of TBW)	58 to 62.8	57.9 to 60.9	57.6 to 60.4	57.2 to 60.2	56.7 to 59.9	56.6 to 59.8	56 to 59.8	55.6 to 59.4	55.7 to 59.9
ECF (liters)	11.3 to 19.3	14.2 to 21.4	15 to 22.4	15.4 to 22.8	15.6 to 23	15.1 to 22.3	14.6 to 21.6	14.1 to 20.5	12.8 to 19
ECF (% of TBW)	37.2 to 42	39.1 to 42.1	39.6 to 42.4	39.8 to 42.8	40.1 to 43.3	40.2 to 43.4	40.2 to 44	40.6 to 44.4	40.1 to 44.3
Fat Mass (lb)	11 to 47.4	21.1 to 61.5	26 to 64.4	29.4 to 66.6	30.4 to 67	31.2 to 65	28.6 to 59.6	25.4 to 54.4	18.4 to 47.6
Fat Mass (%)	12 to 26.8	16.8 to 29.8	29.2 to 30.6	19.6 to 31.2	19.8 to 31.4	20.3 to 31.9	19.5 to 31.1	18.3 to 30.5	15 to 29.4
Fat Free Mass (lb)	88.6 to 136.6	107.3 to 151.3	112 to 157.6	114 to 158.8	115 to 158.6	111.3 to 152.9	106.8 to 146.8	102.5 to 137.7	92.9 to 128.3
Fat Free Mass (%)	73.2 to 88	70.2 to 83.2	69.4 to 81.8	68.8 to 80.4	68.6 to 80.2	68.1 to 79.7	68.9 to 80.5	69.5 to 81.7	70.6 to 85
BMR (cal)	1427.9 to 1958.3	1580.6 to 2093.2	1580.2 to 2087.6	1543.4 to 2045	1486 to 1973.4	1391.9 to 1847.1	1275.6 to 1708.2	1162 to 1543.2	998.1 to 1378.7
BMI	17.7 to 27.1	20.6 to 30.4	21.6 to 31.6	22.6 to 32.4	22.8 to 32.4	23 to 31.8	22.2 to 30.6	21.4 to 29	19.7 to 26.9

*The ranges provided here are not intended to represent a "healthy" or "ideal" range. They are statistical averages of average Americans and are provided for reference only.

REFERENCES
1. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey III (1988-1994). https://www.cdc.gov/nchs/nhanes/nhanes3.htm. Accessed October 25, 2017.

Impedimed. (2017). *Training material | ImpediMed*. www.impedimed.com. https://www.impedimed.com/training/

Appendix R: Reference List

Accardi, A. J., Burns, A., & Haywood, J. T. (2019). Correlation of limb bioimpedance to echocardiographic indicators of congestion in patients with NYHA Class II/III heart failure. *Cardiology & Vascular Research*, *3*(1). https://doi.org/10.33425/2639-8486.1039

Adamson, P. B. (2009). Pathophysiology of the transition from chronic compensated and acute decompensated heart failure: New insights from continuous monitoring devices. *Current Heart Failure Reports*, *6*(4), 287–292. https://doi.org/10.1007/s11897-009-0039-z

American Occupational Therapy Association. (2009). Scholarship in occupational therapy. *American Journal of Occupational Therapy*, *63*(6), 790–796. https://doi.org/10.5014/ajot.63.6.790

American Occupational Therapy Association. (2013). Obesity and occupational therapy. *American Journal of Occupational Therapy*, *67*(6_Supplement), S39–S46. https://doi.org/10.5014/ajot.2013.67s39

American Occupational Therapy Association. (2015). Fact sheet: Occupational therapy's role with chronic disease management. *American Journal of Occupational Therapy*.

American Occupational Therapy Association. (2018). Role of occupational therapy in wound management. *American Journal of Occupational Therapy*, *72*(Supplement_2), 7212410057p1. https://doi.org/10.5014/ajot.2018.72s212

American Occupational Therapy Association. (2020a). *Vision 2025*. aota.org. https://www.aota.org/Publications-News/otp/Archive/2018/Vision-2025.aspx

American Occupational Therapy Association. (2020b). Occupational therapy practice framework: Domain and process – Fourth edition. *American Journal of Occupational Therapy*, *74*(Supplement_2), 7412410010p1. https://doi.org/10.5014/ajot.2020.74s2001

Arias-Guillén, M., Perez, E., Herrera, P., Romano, B., Ojeda, R., Vera, M., Ríos, J., Fontseré, N., & Maduell, F. (2018). Bioimpedance spectroscopy as a practical tool for the early detection and prevention of protein-energy wasting in hemodialysis patients. *Journal of Renal Nutrition*, *28*(5), 324–332. https://doi.org/10.1053/j.jrn.2018.02.004

Asklöf, M., Kjølhede, P., Wodlin, N. B., & Nilsson, L. (2018). Bioelectrical impedance analysis; a new method to evaluate lymphoedema, fluid status, and tissue damage after gynecological surgery - A systematic review. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *228*, 111–119. https://doi.org/10.1016/j.ejogrb.2018.06.024

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of Usability Studies*, *4*(3), 114–123.

Baumann, F. T., Reike, A., Reimer, V., Schumann, M., Hallek, M., Taaffe, D. R., Newton, R. U., & Galvao, D. A. (2018). Effects of physical exercise on breast cancer-related secondary lymphedema: A systematic review. *Breast Cancer Research and Treatment*, *170*(1), 1–13. https://doi.org/10.1007/s10549-018-4725-y

Beaudart, C., Rolland, Y., Cruz-Jentoft, A. J., Bauer, J. M., Sieber, C., Cooper, C., Al-Daghri, N., Araujo de Carvalho, I., Bautmans, I., Bernabei, R., Bruyère, O., Cesari, M., Cherubini, A., Dawson-Hughes, B., Kanis, J. A., Kaufman, J.-M., Landi, F., Maggi, S., McCloskey, E., … Fielding, R. A. (2019). Assessment of muscle function and physical performance in daily clinical practice. *Calcified Tissue International*, *105*.

Björkman, M. P., Jyväkorpi, S. K., Strandberg, T. E., Pitkala, K. H., & Tilvis, R. S. (2019). The associations of body mass index, bioimpedance spectroscopy-based calf intracellular resistance, single-frequency bioimpedance analysis and physical performance of older people. *Aging Clinical and Experimental Research*, *32*. https://doi.org/10.1007/s40520-019-01301-8

Brooke, J. (1986). *SUS -A quick and dirty usability scale*. https://hell.meiert.org/core/pdf/sus.pdf

Buendia, R., Seoane, F., Lindecrantz, K., Bosaeus, I., Gil-Pita, R., Johannsson, G., Ellegård, L., & Ward, L. C. (2015). Estimation of body fluids with bioimpedance spectroscopy: State of the art methods and proposal of novel methods. *Physiological Measurement*, *36*(10), 2171–2187. https://doi.org/10.1088/0967-3334/36/10/2171

Burton, R. F. (2019). Relationships between fat mass and lean mass. *Obesity*, *27*(6), 873–873. https://doi.org/10.1002/oby.22467

Caytak, H., Boyle, A., Adler, A., & Bolic, M. (2019). Bioimpedance Spectroscopy Processing and Applications. *Encyclopedia of Biomedical Engineering*, *3*, 265–279. https://doi.org/10.1016/b978-0-12-801238-3.10884-0

Cole, M. B., & Tufano, R. (2020). *Applied theories in occupational therapy: A practical approach.* Slack.

Cole, M., & Tufano, R. (2008). Ecology of Human Performance. In *Applied Theories in Occupational Therapy: A practical approach*. SLACK.

Desai, A. S. (2012). Home monitoring heart failure care does not improve patient outcomes. *Circulation*, *125*(6), 828–836. https://doi.org/10.1161/circulationaha.111.031179

Dewitte, A., Carles, P., Joannès-Boyau, O., Fleureau, C., Roze, H., Combe, C., & Ouattara, A. (2015). Bioelectrical impedance spectroscopy to estimate fluid balance in critically ill patients. *Journal of Clinical Monitoring and Computing*, *30*(2), 227–233. https://doi.org/10.1007/s10877-015-9706-7 dos Santos, L., Cyrino, E. S., Antunes, M., Santos, D. A., & Sardinha, L. B. (2016a). Changes in phase angle and body composition induced by resistance training in older women. *European Journal of Clinical Nutrition*, *70*(12), 1408–1413. https://doi.org/10.1038/ejcn.2016.124

Du, Z., Wan, H., Chen, Y., Pu, Y., & Wang, X. (2017). Bioimpedance spectroscopy can precisely discriminate human breast carcinoma from benign tumors. *Medicine*, *96*(4), e5970. https://doi.org/10.1097/md.0000000000005970

Dunn, W., Brown, C., & McGuigan, A. (1994). The ecology of human performance: A framework for considering the effect of context. *American Journal of Occupational Therapy*, *48*(7), 595–607. https://doi.org/10.5014/ajot.48.7.595

Ellegård, L., Bertz, F., Winkvist, A., Bosaeus, I., & Brekke, H. K. (2016). Body composition in overweight and obese women postpartum: bioimpedance methods validated by dual energy X-ray absorptiometry and doubly labeled water. *European Journal of Clinical Nutrition*, *70*(10), 1181–1188. https://doi.org/10.1038/ejcn.2016.50

Fazio, L. S. (2017a). *Developing occupation-centered programs with the community*. Slack Incorporated.

Fazio, L. S. (2017b). Practicing occupation in the community. In *Developing occupation-centered programs with the community*. SLACK incorporated.

Fisch, B. J., & Spiegel, D. M. (1996). Assessment of excess fluid distribution in chronic hemodialysis patients using bioimpedance spectroscopy. *Kidney International*, *49*(4), 1105–1109. https://doi.org/10.1038/ki.1996.160

Funk, M., Nystrom, K. V., Hutchinson, C., Katz, S. D., & Lee, F. A. (2003). Bioimpedance monitoring in patients with chronic heart failure. *Journal of Cardiac Failure*, *9*(5), S6. https://doi.org/10.1016/s1071-9164(03)00177-5

Gillen, G., & Nilsen, D. M. (2019). Motor function and occupational performance. In *Willard and Spackman's occupational therapy*. Wolters Kluwer.

Gillespie, T. C., Sayegh, H. E., Brunelle, C. L., Daniell, K. M., & Taghian, A. G. (2018). Breast cancer-related lymphedema: Risk factors, precautionary measures, and treatments. *Gland Surgery*, *7*(4), 379–403. https://doi.org/10.21037/gs.2017.11.04

Gillham, M. B., Hodges, V. A., Davis, J. N., & Meadows, M. R. (2005). Quantifying excess fat free mass in overweight/obese adults. *Journal of the American Dietetic Association*, *105*(8), 17. https://doi.org/10.1016/j.jada.2005.05.046

Han, B. G., Lee, J., Kim, J. S., & Yang, J. W. (2018). Clinical significance of phase angle in non-dialysis CKD stage 5 and peritoneal dialysis patients. *Nutrients*, *10*(9), 1331. https://doi.org/10.3390/nu10091331

Hidding, J. T., Viehoff, P. B., Beurskens, C. H. G., van Laarhoven, H. W. M., Nijhuis-van der Sanden, M. W. G., & van der Wees, P. J. (2016). Measurement properties of instruments for measuring of lymphedema: Systematic review. *Physical Therapy*, *96*(12), 1965–1981. https://doi.org/10.2522/ptj.20150412

Impedimed. (2017). *Training Material | ImpediMed*. www.impedimed.com. https://www.impedimed.com/training/

Impedimed. (2018a). Bioimpedance drawing. In *https://i.ytimg.com/vi/BPpbOoD1Spg/maxresdefault.jpg*.

ImpediMed. (2018b). *Tissue and fluid analysis*. PowerPoint Slides. www.hellosozo.com

ImpediMed. (2018c). What is BIS? - SOZO® Digital Health Platform [YouTube Video]. In *YouTube*. https://www.youtube.com/watch?v=BPpbOoD1Spg&t=15s

ImpediMed. (2020a). *Bioimpedance spectroscopy (BIS) technology | ImpediMed*. www.impedimed.com. https://www.impedimed.com/healthcare/bis-technology/

Impedimed. (2020b). Bioimpedance spectroscopy technology. In *https://www.impedimed.com/healthcare/bis-technology/*.

ImpediMed. (2020c). *Products | ImpediMed*. www.impedimed.com. https://www.impedimed.com/products/

Jack, J., & Estes, R. I. (2010). Documenting progress: Hand therapy treatment shift from biomechanical to occupational adaptation. *American Journal of Occupational Therapy*, *64*(1), 82–87. https://doi.org/10.5014/ajot.64.1.82

Janssen, I., Heymsfield, S. B., Wang, Z., & Ross, R. (2000). Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. *Journal of Applied Physiology*, *89*(1), 81–88. https://doi.org/10.1152/jappl.2000.89.1.81

Joskova, V., Patkova, A., Havel, E., Najpaverova, S., Uramova, D., Kovarik, M., Zadak, Z., & Hronek, M. (2019). The bioimpedance spectroscopy as useful tool for measuring the fluid excess and fluid management in severe polytrauma patients. *Physiological Research*, 255–264. https://doi.org/10.33549/physiolres.933953

Kataoka, H. (2009). Novel monitoring method for the management of heart failure: Combined measurement of body weight and bioimpedance index of body fat percentage. *Future Cardiology*, *5*(6), 541–546. https://doi.org/10.2217/fca.09.47

Kaysen, G. A., Zhu, F., Sarkar, S., Heymsfield, S. B., Wong, J., Kaitwatcharachai, C., Kuhlmann, M. K., & Levin, N. W. (2005). Estimation of total-body and limb muscle mass in hemodialysis patients by using multifrequency bioimpedance spectroscopy. *The American Journal of Clinical Nutrition*, *82*(5), 988–995. https://doi.org/10.1093/ajcn/82.5.988

Keane, D. F., Baxter, P., Lindley, E., Moissl, U., Pavitt, S., Rhodes, L., & Wieskotten, S. (2017). The body composition monitor: A flexible tool for routine fluid management across the hemodialysis population. *Biomedical Physics & Engineering Express*, *3*(3), 035017. https://doi.org/10.1088/2057-1976/aa6f45

Kenworthy, P., Grisbrook, T. L., Phillips, M., Gittings, P., Wood, F. M., Gibson, W., & Edgar, D. W. (2017). Bioimpedance spectroscopy: A technique to monitor interventions for swelling in minor burns. *Burns*, *43*(8), 1725–1735. https://doi.org/10.1016/j.burns.2017.04.022

Kenworthy, P., Phillips, M., Grisbrook, T. L., Gibson, W., Wood, F. M., & Edgar, D. W. (2018). Monitoring wound healing in minor burns—A novel approach. *Burns*, *44*(1), 70–76. https://doi.org/10.1016/j.burns.2017.06.007

Khalil, S., Mohktar, M., & Ibrahim, F. (2014). The theory and fundamentals of bioimpedance analysis in clinical status monitoring and diagnosis of diseases. *Sensors*, *14*(6), 10895–10928. https://doi.org/10.3390/s140610895

Khan, A., Khan, A. H., Adnan, A. S., Sulaiman, S. A. S., Ahmad, N., & Gan, S. H. (2018). Evaluation of factors affecting time to achieve dry weight among hemodialysis patients using bioimpedance spectroscopy. *Irish Journal of Medical Science (1971 -)*, *188*(1), 311–319. https://doi.org/10.1007/s11845-018-1813-2

Khan, Y. H., Sarriff, A., Adnan, A. S., Khan, A. H., & Mallhi, T. H. (2016). Diuretics prescribing in chronic kidney disease patients: physician assessment versus bioimpedance spectroscopy. *Clinical and Experimental Nephrology*, *21*(3), 488–496. https://doi.org/10.1007/s10157-016-1303-7

Kilgore, L. J., Korentager, S. S., Hangge, A. N., Amin, A. L., Balanoff, C. R., Larson, K. E., Mitchell, M. P., Chen, J. G., Burgen, E., Khan, Q. J., O'Dea, A. P., Nye, L., Sharma, P., & Wagner, J. L. (2018). Reducing breast cancer-related lymphedema (BCRL) through prospective surveillance monitoring using bioimpedance spectroscopy (BIS) and patient directed self-interventions. *Annals of Surgical Oncology*, *25*(10), 2948–2952. https://doi.org/10.1245/s10434-018-6601-8

Kim, E. J., Choi, M. J., Lee, J. H., Oh, J. E., Seo, J. W., Lee, Y. K., Yoon, J. W., Kim, H. J., Noh, J. W., & Koo, J. R. (2017). Extracellular fluid/intracellular fluid volume ratio as a novel risk indicator for all-cause mortality and cardiovascular disease in hemodialysis patients. *PLOS ONE*, *12*(1), e0170272. https://doi.org/10.1371/journal.pone.0170272

Kittiskulnam, P., Chertow, G. M., Carrero, J. J., Delgado, C., Kaysen, G. A., & Johansen, K. L. (2017). Sarcopenia and its individual criteria are associated, in part, with mortality among patients on hemodialysis. *Kidney International*, *92*(1), 238–247. https://doi.org/10.1016/j.kint.2017.01.024

Klug, B. (2017). An overview of the system usability scale in library website and system usability testing. *Weave: Journal of Library User Experience*, *1*(6). https://doi.org/10.3998/weave.12535642.0001.602

Koelmeyer, L. A., Ward, L. C., Dean, C., & Boyages, J. (2020). Body positional effects on bioimpedance spectroscopy measurements for lymphedema assessment of the arm. *Lymphatic Research and Biology*, *18*(1). https://doi.org/10.1089/lrb.2019.0067

Kuchnia, A. J., Yamada, Y., Teigen, L., Krueger, D., Binkley, N., & Schoeller, D. (2018). Combination of DXA and BIS body composition measurements is highly correlated with physical function—An approach to improve muscle mass assessment. *Archives of Osteoporosis*, *13*(1). https://doi.org/10.1007/s11657-018-0508-7

Lattie, E. G., Bass, M., Garcia, S. F., Phillips, S. M., Moreno, P. I., Flores, A. M., Smith, J., Scholtens, D., Barnard, C., Penedo, F. J., Cella, D., & Yanez, B. (2020). Optimizing health information technologies for symptom management in cancer patients and survivors: Usability evaluation. *JMIR Formative Research*, *4*(9), e18412. https://doi.org/10.2196/18412

Levenhagen, K., Davies, C., Perdomo, M., Ryans, K., & Gilchrist, L. (2017). Diagnosis of upper quadrant lymphedema secondary to cancer: Clinical practice guideline from the oncology section of the American Physical Therapy Association. *Physical Therapy*, *97*(7), 729–745. https://doi.org/10.1093/ptj/pzx050

McMillian, I. R. (2016, September 9). *The biomechanical frame of reference in occupational therapy*. Musculoskeletal key. https://musculoskeletalkey.com/the-biomechanical-frame-of-reference-in-occupational-therapy/

Merks, P., Religioni, U., Arciszewska, K., Pankiewicz, W., Jaguszewski, M., & Vaillancourt, R. (2020). Usability testing and satisfaction of "The Patient Access": A mobile health application for patients with venous thromboembolic disease. A pilot study. *Cardiology Journal*. https://doi.org/10.5603/cj.a2020.0107

Minett, M. M., Binkley, T. L., Holm, R. P., Runge, M., & Specker, B. L. (2020). Feasibility and effects on muscle function of an exercise program for older adults. *Medicine & Science in Sports & Exercise*, *52*(2), 441–448. https://doi.org/10.1249/mss.0000000000002152

Moloney, E. C., Brunner, M., Alexander, A. J., & Clark, J. (2014). Quantifying fibrosis in head and neck cancer treatment: An overview. *Head & Neck*, *37*(8), 1225–1231. https://doi.org/10.1002/hed.23722

Moon, J. R., Smith, A. E., Tobkin, S. E., Lockwood, C. M., Kendall, K. L., Graef, J. L., Roberts, M. D., Dalbo, V. J., Kerksick, C. M., Cramer, J. T., Beck, T. W., & Stout, J. R. (2009). Total body water changes after an exercise intervention tracked using bioimpedance spectroscopy: A deuterium oxide comparison. *Clinical Nutrition*, *28*(5), 516–525. https://doi.org/10.1016/j.clnu.2009.04.025

Naranjo-Hernández, D., Reina-Tosina, J., & Min, M. (2019). Fundamentals, recent advances, and future challenges in bioimpedance devices for healthcare applications. *Journal of Sensors*, *2019*, 1–42. https://doi.org/10.1155/2019/9210258

National Institute on Health. (2019). *Assessing Your Weight and Health Risk*. Nih.Gov. https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm

Nicholls, G. M., & Richards, M. A. (2007). Disease monitoring of patients with chronic heart failure. *Heart*, *93*(4), 519–523. https://doi.org/10.1136/hrt.2005.078519

Norberg, E.-B., Boman, K., Löfgren, B., & Brännström, M. (2014). Occupational performance and strategies for managing daily life among the elderly with heart failure. *Scandinavian Journal of Occupational Therapy*, *21*(5), 392–399. https://doi.org/10.3109/11038128.2014.911955

Nussbaum, J., & Garcia, R. K. (2009). Restorative physical and occupational therapy: A critical need for patients with chronic kidney and end-stage renal disease. *Advances in Chronic Kidney Disease*, *16*(6), 529–535. https://doi.org/10.1053/j.ackd.2009.08.001

Padwal, R., Majumdar, S. R., & Leslie, W. D. (2016). Relationship among body fat percentage, body mass index, and all-cause mortality. *Annals of Internal Medicine*, *165*(8), 604. https://doi.org/10.7326/l16-0334

Peppa, M., Stefanaki, C., Papaefstathiou, A., Boschiero, D., Dimitriadis, G., & Chrousos, G. (2017). Bioimpedance analysis vs. DEXA as a screening tool for osteosarcopenia in lean, overweight and obese Caucasian post-menopausal females. *HORMONES*, *16*(2). https://doi.org/10.14310/horm.2002.1732

Pichler, G. P., Amouzadeh-Ghadikolai, O., Leis, A., & Skrabal, F. (2013). A critical analysis of whole body bioimpedance spectroscopy (BIS) for the estimation of body compartments in health and disease. *Medical Engineering & Physics*, *35*(5), 616–625. https://doi.org/10.1016/j.medengphy.2012.07.006

Pichonnaz, C., Bassin, J. P., Lécureux, E., Currat, D., & Jolles, B. M. (2015). Bioimpedance spectroscopy for swelling evaluation following total knee arthroplasty: A validation study. *BMC Musculoskeletal Disorders*, *16*(1). https://doi.org/10.1186/s12891-015-0559-5

Qin, E. S., Bowen, M. J., & Chen, W. F. (2018). Diagnostic accuracy of bioimpedance spectroscopy in patients with lymphedema: A retrospective cohort analysis. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *71*(7), 1041–1050. https://doi.org/10.1016/j.bjps.2018.02.012

Reitz, S. M., & Scaffa, M. E. (2020). Occupational therapy in the promotion of health and well-being. *American Journal of Occupational Therapy*, *74*(3), 7403420010p1. https://doi.org/10.5014/ajot.2020.743003

Rice University. (2013, March 6). *26.1 body fluids and fluid compartments – anatomy and physiology*. Opentextbc.Ca. https://opentextbc.ca/anatomyandphysiology/chapter/26-1-body-fluids-and-fluid-compartments/

Ridner, S. H., Dietrich, M. S., Cowher, M. S., Taback, B., McLaughlin, S., Ajkay, N., Boyages, J., Koelmeyer, L., DeSnyder, S. M., Wagner, J., Abramson, V., Moore, A., & Shah, C. (2019). A randomized trial evaluating bioimpedance spectroscopy versus tape measurement for the prevention of lymphedema following treatment for breast cancer: Interim analysis. *Annals of Surgical Oncology*, *26*(10), 3250–3259. https://doi.org/10.1245/s10434-019-07344-5

Rural Health Information Hub. (2011). *Defining Health Promotion and Disease Prevention - RHIhub Toolkit*. Ruralhealthinfo.Org. https://www.ruralhealthinfo.org/toolkits/health-promotion/1/definition

Ryan, A. M., Prado, C. M., Sullivan, E. S., Power, D. G., & Daly, L. E. (2019). Effects of weight loss and sarcopenia on response to chemotherapy, quality of life, and survival. *Nutrition*, *67–68*, 110539. https://doi.org/10.1016/j.nut.2019.06.020

Samson, K. (2019). Bioimpedance spectroscopy tracks lymphedema more accurately. *Oncology Times*, *41*(12), 18. https://doi.org/10.1097/01.cot.0000569284.27775.14

Sandek, A., & Rauchhaus, M. (2007). Use of bioimpedance analysis in patients with chronic heart failure? *European Journal of Heart Failure*, *9*(1), 105–105. https://doi.org/10.1016/j.ejheart.2006.10.009

Sauro, J. (2013). *MeasuringU: 10 things to know about the system usability scale (SUS)*. measuringu.com. https://measuringu.com/10-things-sus/

Savarese, G., & Lund, L. H. (2017). Global public health burden of heart failure. *Cardiac Failure Review*, *03*(01), 7. https://doi.org/10.15420/cfr.2016:25:2

Schell, B. A., & Gillen, G. (2019). *Willard and Spackman's occupational therapy*. Wolters Kluwer.

Seoane, F., Reza Atefi, S., Tomner, J., Kostulas, K., & Lindecrantz, K. (2015). Electrical bioimpedance spectroscopy on acute unilateral stroke patients: Initial observations regarding differences between sides. *BioMed Research International*, *2015*, 1–12. https://doi.org/10.1155/2015/613247

Serra-Prat, M., Lorenzo, I., Palomera, E., Ramírez, S., & Yébenes, J. C. (2018). Total body water and intracellular water relationships with muscle strength, frailty and functional performance in an elderly population. A cross-sectional study. *The Journal of Nutrition, Health & Aging*, *23*(1), 96–101. https://doi.org/10.1007/s12603-018-1129-y

Seward, C., Skolny, M., Brunelle, C., Asdourian, M., Salama, L., & Taghian, A. G. (2016). A comprehensive review of bioimpedance spectroscopy as a diagnostic tool for the detection and measurement of breast cancer-related lymphedema. *Journal of Surgical Oncology*, *114*(5), 537–542. https://doi.org/10.1002/jso.24365

Shah, C., Vicini, F. A., & Arthur, D. (2016). Bioimpedance spectroscopy for breast cancer related lymphedema assessment: Clinical practice guidelines. *The Breast Journal*, *22*(6), 645–650. https://doi.org/10.1111/tbj.12647

Soran, A., Ozmen, T., McGuire, K. P., Diego, E. J., McAuliffe, P. F., Bonaventura, M., Ahrendt, G. M., DeGore, L., & Johnson, R. (2014). The importance of detection of subclinical lymphedema for the prevention of breast cancer-related clinical lymphedema after axillary lymph node dissection; A prospective observational study. *Lymphatic Research and Biology*, *12*(4), 289–294. https://doi.org/10.1089/lrb.2014.0035

Steinwandel, U., Gibson, N., Towell-Barnard, A., Parsons, R., Rippey, J., & Rosman, J. (2019). Does the intravascular volume status in hemodialysis patients measured by inferior vena cava ultrasound correlate with bioimpedance spectroscopy? *Journal of Clinical Nursing*, *28*(11–12), 2135–2146. https://doi.org/10.1111/jocn.14804

Stern, B. Z. (2018). Critical reflections on self-management support in chronic disease: The value of occupational therapy in health promotion. *The Open Journal of Occupational Therapy*, *6*(4). https://doi.org/10.15453/2168-6408.1461

St. Onge, M.-P., Wang, J., Shen, W., Wang, Z., Allison, D. B., Heshka, S., Pierson, R. N., & Heymsfield, S. B. (2004). Dual-energy X-ray absorptiometry-measured lean soft tissue mass: Differing relation to body cell mass across the adult life span. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *59*(8), B796–B800. https://doi.org/10.1093/gerona/59.8.b796

Tinsley, G. M., Graybeal, A. J., Moore, M. L., & Nickerson, B. S. (2019). Fat-free mass characteristics of muscular physique athletes. *Medicine & Science in Sports & Exercise*, *51*(1), 193–201. https://doi.org/10.1249/mss.0000000000001749

Tinsley, G. M., Morales, E., Forsse, J. S., & Grandjean, P. W. (2017). Impact of acute dietary manipulations on DXA and BIA body composition estimates. *Medicine & Science in Sports & Exercise*, *49*(4), 823–832. https://doi.org/10.1249/mss.0000000000001148

Tsuchiya, M., Mori, M., Takahashi, M., & Masujima, M. (2018). Community-based lymphedema risk reduction programs for cancer survivors: An internet survey of public health nurses. *Japan Journal of Nursing Science*, *15*(4), 340–350. https://doi.org/10.1111/jjns.12204

Turpin, M., & Iwama, M. K. (2011). *Using occupational therapy models in practice : A field guide*. Elsevier.

Uemura, K., Doi, T., Tsutsumimoto, K., Nakakubo, S., Kim, M., Kurita, S., Ishii, H., & Shimada, H. (2019). Predictivity of bioimpedance phase angle for incident disability in older adults. *Journal of Cachexia, Sarcopenia and Muscle*, *11*. https://doi.org/10.1002/jcsm.12492

usabiliTEST. (2011). *Usability testing and information architecture tools for everyone*. www.usabilitest.com. https://www.usabilitest.com/pro/?ux=Bl4ONgAQFRl7T1dFRV5URB8RVhYXf3YPV1IBBgEQN1wHRmcHFhczXEdMXkNACgAVSg1cEl5CU1AKBjo3NDZmMWJiNQ%3D%3D

Vance, K., Miller, C., & McGlamery, J. N. (2020). Improving outcomes in chronic conditions: Occupational therapy's distinct value in PDGM. *SIS Quarterly Practice Connections*, *5*(2), 15–18.

van der Sande, F. M., van de Wal-Visscher, E. R., Stuard, S., Moissl, U., & Kooman, J. P. (2019). Using bioimpedance spectroscopy to assess volume status in dialysis patients. *Blood Purification*, *49*(1–2), 178–184. https://doi.org/10.1159/000504079

Walowski, C. O., Braun, W., Maisch, M. J., Jensen, B., Peine, S., Norman, K., Müller, M. J., & Bosy-Westphal, A. (2020). Reference values for skeletal muscle mass – current concepts and methodological considerations. *Nutrients*, *12*(3), 755. https://doi.org/10.3390/nu12030755

Ward, L. C., Czerniec, S., & Kilbreath, S. L. (2008). Quantitative bioimpedance spectroscopy for the assessment of lymphoedema. *Breast Cancer Research and Treatment*, *117*(3), 541–547. https://doi.org/10.1007/s10549-008-0258-0

Ward, L. C., Dylke, E. S., & Kilbreath, S. L. (2012). Measurement of hand volume by bioelectrical impedance spectroscopy. *Lymphatic Research and Biology*, *10*(2), 81–86. https://doi.org/10.1089/lrb.2012.0005

Warren, A. G., Brorson, H., Borud, L. J., & Slavin, S. A. (2007). Lymphedema. *Annals of Plastic Surgery*, *59*(4), 464–472. https://doi.org/10.1097/01.sap.0000257149.42922.7e

Warren, A. G., Janz, B. A., Slavin, S. A., & Borud, L. J. (2007). The use of bioimpedance analysis to evaluate lymphedema. *Annals of Plastic Surgery*, *58*(5), 541–543. https://doi.org/10.1097/01.sap.0000244977.84130.cf

Weyer, S., Zink, M. D., Wartzek, T., Leicht, L., Mischke, K., Vollmer, T., & Leonhardt, S. (2014). Bioelectrical impedance spectroscopy as a fluid management system in heart failure. *Physiological Measurement*, *35*(6), 917–930. https://doi.org/10.1088/0967-3334/35/6/917

World Health Organization: WHO. (2019, November 15). *Health promotion*. Who.Int; World Health Organization: WHO. https://www.who.int/health-topics/health-promotion#tab=tab_1

Yanek, L. R., Vaidya, D., Kral, B. G., Dobrosielski, D. A., Moy, T. F., Stewart, K. J., & Becker, D. (2015). Lean mass and fat mass as contributors to physical fitness in an overweight and obese African American population. *Ethn Dis.*, *25*(2), 214–219.

Yoo, C., Kim, J., Yang, Y., Lee, J., & Jeon, G. (2016). Bioelectrical impedance analysis for severe stroke patients with upper extremity hemiplegia. *Journal of Physical Therapy Science*, *28*(10), 2708–2712. https://doi.org/10.1589/jpts.28.2708-2712

Yu, C. M., Wang, L., Chau, E., Chan, R. H. W., Kong, S. L., Tang, M. O., Christensen, J., Stadler, R. W., & Lau, C.-P. (2005). Intrathoracic impedance monitoring in patients with heart failure. *Circulation*, *112*(6), 841–848. https://doi.org/10.1161/circulationaha.104.492207