Protocol Title: Evaluation of the accuracy of a computer vision-based tool for assessment of total body fat percentage

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IRB Review History:
This is a new protocol. The study subjects will be evaluated at Pennington Biomedical Research Center (PBRC) and Massachusetts General Hospital (MGH). Amazon will fund the study.

The study is cross-sectional and will include 132 subjects evenly divided across two clinical sites. Approximately half of the participants will be recruited and evaluated at each center.

Objectives:
The aim of this study is to acquire 2D electronic images of the adult human body with a novel computer vision tool (VBC) and to compare these images to corresponding body composition as measured by dual-energy x-ray absorptiometry (DXA), Bod Pod, several bioimpedance analysis (BIA) systems, and previously validated 3D optical devices. The VBC is incorporated into a cell phone and use involves capture of multiple participant images that are then used with the device app to generate body fat estimates.

Hypothesis:
We hypothesize that the VBC device will be equal to or more accurate than clinical grade (DXA, Bod Pod) and BIA systems for measuring body composition.

Background:
Optical imaging systems are rapidly evolving and are now increasingly being used in research, clinical, and home settings. The VBC 2D imaging device operates through a smart-phone and provides the user with estimates of percent body fat and other body composition estimates. The VBC is not intended for any diagnostic use, is a general-purpose wellness device based on the FDA's Mobile Medical Application and General Wellness guidance, and is thus exempt from IND requirements.

Aims:
The study hypothesis will be tested as follows. Each subject will complete VBC, DXA, anthropometric, BodPod, and BIA analysis at either PBRC or MGH. The acquired data will then be used to accomplish the specific aims:

1. Identify the associations of body composition acquired by the VBC with those estimated by DXA, BodPod, and BIA.

2. Describe the precision and accuracy of the VBC-derived scans.

Subjects and Design:
We will recruit a stratified sample of 132 participants recruited from the Baton Rouge or Boston metropolitan area for this study over a span of two months. Participants will be further subdivided into cohorts based on gender, age, and BMI. Participants will be provided a cash compensation ($75) for their voluntary participation in this study.

- Gender:
  - Male: At least 33%
  - Female: At least 33%
- Age:
  - 21-40 years: At least 20%
  - 41-60 years: At least 33%
  - 61-80 years: At least 10%
- BMI (kg/m^2):
  - 18.5-24.9: At least 15%
  - 25-29.9: At least 15%
  - 30-34.9: At least 15%
  - 35-39.9: At least 10%
  - >40: At least 7.5%

The participants will be community dwelling and have no life-threatening conditions or diseases that would alter their body composition from what is typical for their age, sex, ethnicity, and BMI. Overall, participants must be ambulatory, able to withstand lying flat on the DXA table for up to 10 minutes, stand without aid for 2 minutes, weigh less than 440 lbs and be of generally good health.

Inclusion:
- Being either male or female
- Being from 21 to 80 years of age
- Having a body weight of less than 440 pounds
- Being willing to comply with the study procedures

Exclusion:
- Being pregnant or attempting to become pregnant
- Having medical implants such as a pacemaker or metal joint replacements
- Having undergone any previous body altering procedures such as breast augmentation or amputation
- Having a body weight greater than 440 pounds

Each subject enrolled in the study will undergo an initial screening that includes the collection of their body weight, height, vital signs, and urine (women of child bearing potential). Additional testing will be done with the participant minimally clothed in a pair of spandex shorts and a sports bra (if female) and will include a whole body DXA scan

(x1), several BIA measurements (x2), a BodPod measurement (x1), VBC system measurements (x2 scans) and 3D optical scans (x2).

Study Visit Sequence

The below sequence of events describes what will occur during participant visits. All testing will follow the consenting process, but not necessarily in the order listed below.

Sequence	Procedure
Arrive at clinical site	Consenting Process
Outpatient Clinic	Vital signs; Urine Pregnancy Testing in Women of Childbearing Potential; Body Weight/Height
3D optical body scans	Digitally measure anthropometrics and body composition
Anthropometrics	Circumferences with tape measure
2D imaging with VBC	Automatically measure body dimensions with VBC device
Dual-Energy X-ray Absorptiometry	Measure body composition
Bioelectrical Impedance	Measure body composition – multiple devices
BodPod	Measure body volume and composition
Complete Study	

Recruitment and Screening Methods:
Subjects will be recruited through web-based questionnaires, direct phone calls, media, and community outreach. Multiple forms of communication including paid advertisements such as print/social media/mass media etc. will be used to market the study and direct potential participants to complete the web screener application. In addition, the Recruitment Department will participate in regional health events in which study information will be available to those interested in screening. A recruiter would then follow up with that participant to pre-screen them for the study.

The web screener / phone screening process will include the participant filling out basic health information, demographic information, as well as risk factors for metabolic conditions**.** A recruiter will follow up with all participants who are eligible via the web screener, phone in to the recruitment department, or show interest at a community event. If the subject is eligible, the recruiter will schedule their study visit.

Upon completion of the study visit, the subject will receive $75.

A copy of the consent will be provided to subjects at the time of study visit. Subjects will be consented in a private room, and they can contact the investigators should any questions arise.

Women of childbearing potential will complete a urine pregnancy test. The full evaluation will begin following these initial steps.

The subject will then fill out an electronic questionnaire regarding dietary history and physical activity.

Participants will be asked to arrive in gym-style clothing or clothing that is easily removable, as they will be in form-fitting garments for all VBC scans, BIA, DXA, tape measurements, BodPod, and 3D optical evaluations. Participants will be required to change into a form-fitting wardrobe and swim cap that we will provide for the Bod Pod procedure. We will have five freshly washed top and bottom garments in sizes small, medium, large, X-large, and XX-large.

Study Timelines:
The duration anticipated to enroll all study subjects is two months. The duration of an individual subject's participation is less than three hours.

Study Endpoints:
The first aim is to recruit 132 participants stratified to cover the range of body sizes, BMI values, and ages for both sexes.

Measurements:
All subjects will have body circumferences, DXA, Bod Pod, BIA, and VBC measurements. Note that times listed below include the subject moving from one lab to another.

Baseline evaluations: (about 15 minutes):
Trained staff will take a series of body measurements. These measurements include height, weight, and vital signs. The subject's BMI will be calculated from these measurements.

Body Composition Measurements

Circumferences (about 15 minutes):
Circumferences of the waist, hip, neck, right upper arm and right thigh will be measured. A trained clinical coordinator using a calibrated tape measure will make the circumference measurements. We have an anthropometric training and validation program in place from earlier studies. These measurements will be made in about 15 minutes.

2D (VBC) imaging, (about 5 minutes):
Body Composition will be measured using the VBC system that takes under 60 seconds per scan. Image capture for VBC will include taking a series of four photos using a smartphone camera. Data from the camera will be downloaded to a local computer and then securely sent to the cloud for automated analysis and results generation. We will conduct two consecutive scans (image captures) for each research participant.

Dual-energy x-ray absorptiometry (DXA), (single measurement, about 20 minutes):
This scan measures the amount of bone, muscle, and fat, along with the mass of the head, arms, trunk, and legs. The scan will be performed using a whole-body scanner (Discovery System). The subject will be required to remove all metal-containing objects from the body and to lie down on the table. The subject will be carefully positioned on the table. A scanner emitting low energy X-rays and a detector will pass along the body. The subject will be asked to remain completely still while the scan is in progress. Women of childbearing potential undergoing DXA will have a negative pregnancy test. DXA system operated according to manufacturer specifications.

Bioelectrical Impedance Analysis (BIA), (about 5 minutes):
These tests will measure the amount of fat in the body. The subject will be asked to remove all footwear and socks/stockings. Once changed and barefoot, the subject will be asked to stand on a scale (similar to a large gym scale) and to hold on to hand electrodes on each side of the scale. The subject will be asked to step off the scale once the measurement is complete (less than one minute).

- Professional BIA system (Inbody or SECA)
- At-home smart scales (Fitbit, Etekcity, Tanita)

BodPod (, about 30 minutes):
This test will estimate the amount of fat mass and fat-free mass in the body. The subject will step onto a scale for a quick weight measurement. Next, the subject will sit inside of the system, and the door of the system will be closed. The subject will have a window to see outside of the system while the measurements are completed. The actual measurements will be completed in about 15 minutes.

3D imaging, (about 15 minutes at PBRC only):
Circumferences and body volume will be digitally measured using 3D imaging systems. We will scan each subject 2-3 times per machine; each scan taking approximately 45 seconds.

Quality Control:
All study procedures (BIA, BodPod, 2D imaging, DXA, anthropometry, etc.) will be calibrated and QC done according to Pennington, MGH, and manufacturer guidelines.

Provisions to Monitor the Data to Ensure the Safety of Subjects:
This study is cross-sectional and includes patients screened for potential exclusions such as metal implants and pregnancy (history and urine screen at time of DXA). All subjects will be informed of study risks related to DXA scanning. The investigators will monitor incoming patient data coherence (both hard copy and electronic files) on a

weekly basis as part of quality control procedures. Any adverse events experienced by subjects while participating in the protocol will be reported to the medical investigator and appropriate actions will be taken. A log of adverse events will be kept by the study coordinator and reviewed periodically with the study investigators.

Withdrawal of Subjects:
Subjects can voluntarily decline to participate in the study at any time point during the one day scheduled evaluation.

Risks:

Bioimpedance Analysis: There are no known risks associated with this test. However, patients with medical implants such as a pacemaker or metal joint replacements cannot be measured on the BIA machines. Women who are pregnant will not be evaluated in this study.

VBC Imaging: The faces of each participant will not be captured at the time of acquisition such that their identity will not be possible from the saved images.

DXA: Subjects will be recruited who will be able to access and lie comfortably on the DXA scanner. All procedures will be performed by trained personnel who can provide physical assistance to get on a DXA scanner table. A staff member from the research team will accompany the subjects throughout all the tests.

DXA scans involve exposure to radiation. This radiation exposure is not necessary for medical care and is for research purposes only. The amount of radiation that each subject will receive as a result of participating in this study is estimated to be less than 30 μSv (micro Sieverts or 10-6 Sieverts). This amount of radiation is equivalent to approximately four days of natural background at sea level, much less than the annual natural background radiation in the US, which is 3 mSv (milli Sievert or 10-3 Sievert). This amount of radiation involves minimal risk. Individuals who are pregnant will not be enrolled in this study. Urine testing will confirm that women of childbearing potential are not pregnant prior to DXA evaluation.

3D Optical Imaging Risks: The 3 dimensional optical scans are not a standard procedure for patients; however, it does not involve using the imaging cameras in an unusual way. The optical scans require subjects to stand straight for approximately 1 minute. Two of the scanners involve standing on a small rotating platform. Subjects can halt the scan at any time using hand-held buttons. The faces of each participant will be blurred at the time of acquisition such that their identity will not be possible from the saved images.

Privacy Risks: Participation in research involves some loss of privacy. We will take all available measures to ensure that subject information is kept confidential. If information from this study is published or presented at scientific meetings, all names and other personal identifying information will not be used.

All study electronic data including the optical images will be stored on the password protected computers operated by the Heymsfield Group. These are kept in locked rooms.

Pennington will safeguard data as required by local information security policies. All local site investigators will conduct the study appropriately and be under the supervision of Drs. Heymsfield. All non-compliance with the study protocol or applicable requirements will be reported in accordance with Pennington policy.

Potential Benefits to Subjects:
Establishing a low-cost, non-ionizing procedure to measure body composition and relate them to DXA and other currently available measures may be of value to society to identify individual risks for diabetes and CVD.

Subjects will be provided a copy of their DXA scan and learn their body composition, including bone density. This will provide new and potential useful health information that can be provided at follow-up to their health care provider.

Vulnerable Populations:
The research does not involve individuals who are vulnerable to coercion or undue influence.

Sharing of Results with Subjects:
Subjects will be provided a copy of their DXA, BIA, and 3D optical scans that can be shared, if wanted, with their health care provider.

Setting:
The study will be carried out at PBRC and MGH. Certified radiological technicians at both clinical sites will conduct the DXA scans.

Personnel Responsible for the Safety Review and its Frequency:
The co-principal investigators (Drs. Heymsfield and Stanford) will be responsible for monitoring the data, assuring protocol compliance, and conducting the safety reviews at the specified frequency of once per month. During the review process, Drs. Heymsfield and Stanford will evaluate whether the study should continue unchanged, require modification/ amendment, or close to enrollment.

The PI's and the Institutional Review Board (IRB) have the authority to stop or suspend the study or require modifications.

This protocol presents minimal risks to the subjects, and adverse events or other problems are not anticipated. In the unlikely event that such events occur, Drs. Heymsfield and Stanford are responsible for reporting serious, unanticipated and related adverse events or unanticipated problems involving risks to subjects or others to the IRB. Drs. Heymsfield and Stanford will apprise fellow investigators and study personnel of all adverse events that occur during the conduct of this research project through regular study meetings and via email.

Employee participation:
PBRC or MGH employees who participate in this research protocol will do so voluntarily, and of their own free will. None of those enrolled in this project will report to any of the study investigators, including the Principal Investigators.

Timeframe:
The study will be completed over two months

Statistical Design and Analysis:
Drs. Heymsfield and Stanford will analyze the data using JMP, Excel, and other conventional software. Regression analysis will be used to test the main study hypothesis with %fat measured by the VBC device and by DXA as the reference method. Similar comparisons will be made for the other test systems (e.g., BIA). A secondary series of analyses will be conducted using BodPod as the reference method. Bland-Altman plots will be used to detect between-method bias. Coefficient of variations will be calculated using the duplicate measurements acquired by the VBC and other test systems.

Data Banking:
The de-identified data will be stored on the network shares at PBRC and MGH. No study data will be kept on the lab computer at the clinical sites. Hard copy records for each subject will be kept in the participant's chart located in the Medical Records Department. These data will be used in publications but not shared outside of the PI's use.

Data Sharing with the Sponsor:
The images captured by the data collection app will be shared with Amazon.

Sharing of Results with Subjects:
The DXA, BIA, and 3D optical systems have hard-copy printouts with results of interest or that may be of value to subjects. These printouts will be provided to the subjects and can be reviewed with Dr. Heymsfield and Stanford or the lab manager should questions arise.

Protecting Data Confidentiality:
Data in the current study will be protected so that it is HIPPA compliant as follows:

- The data will only be on a network-shared drive and not on the local computer.
- All people at Pennington and MGH with access to the data will have HIPAA training.
- Any users connecting to the data will use Pennington or MGH network share.

Measurements to be acquired in VBC Study

Clinic
Consenting, Vital signs
Body Composition-Metabolism Lab
3D optical scans
Anthropometry: circumferences
Bioimpedance Analysis: Several systems
BodPod: Body volume measurements
VBC Measurements:
DXA Lab
DXA Measurements: Fat mass (arms, legs, trunk, total), Lean mass (arms, legs, trunk, total), percent fat (arms, legs, trunk, total), Volumes (arms, legs, trunk, total), muscle mass (appendicular, total); Visceral Adipose Tissue (VAT), Subcutaneous Abdominal Adipose Tissue (SAT), Trunk fat to leg fat ratio, Trunk to leg volume ratio, fat mass index (FMI), fat-free mass index (FFMI); Bone mass (arms, legs, lumbar spine, total), Bone Mineral Density (spine, total)