Open-Source, Markerless Motion Tracking for Sagittal Plane Kinematic Analysis

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Disclosures: None

INTRODUCTION: Marker-based motion capture is the gold standard for accurately determining body kinematics. However, this state-of-the-art marker-based tracking approach is expensive, requires significant subject preparation, and is difficult to perform outside of the controlled laboratory environment. In the past several years markerless motion tracking using machine learning have been developed, however, the best of these approaches require significant data sets for model training, are expensive, or require relatively powerful computers to run. Recently, a new approach has been developed called Free Mocap. This software is free to use and download and can be used from a simple consumer grade computer web-cam. The system is calibrated using a printed QR code. The objective of this study is to validate this marker less motion capture system for lower body sagittal kinematics in comparison to the gold standard marker-based motion capture system. This markerless motion tracking system has potential to allow for human kinematic research in a variety of environments, including community situated venues to allow for easier, more representative subject recruitment.

METHODS:
Prior to collection, both the marker-based (motion monitor, Chicago, IL,USA) and markerless systems (FreeMocap.org) were calibrated. A total of 12 test subjects participated in IRB-approved (Fairfield IRB # 4081) human subject data collection (6 male, age=20.2 ± 1.4). Following a signed consent form, each subject was attached with marker clusters for the thorax, sacrum, right upper arm, right thigh, right shank, and right foot regions. Subjects were then digitized using the marker-based system. Following the capture of an "A pose" facing the camera (Figure 1), the subject was positioned with their sagittal plane facing the markerless motion camera (the built-in webcam in the laptop). Each subject performed three movements; ten squats, ten double leg heel raises, and five counter movement jumps. Marker based and markerless motion capture were synchronized using cross correlation and resampled to a 50 Hz frequency. Flexion angles were calculated from the marker-based system using built in algorithms while joint angles were computed from joint positions in provided by the markerless system using the dot-product. We calculated differences between the gold standard marker-based system and markerless system for each of the movement types across all subjects using the Coefficient of Multiple Correlations (CMC). These coefficients range from 0 to 1 where a higher value represent greater agreement between two measurement methods. Specifically, r values between 0 to 0.36 represent poor agreement, 0.36 to 0.67 represent moderate agreement, 0.67 to 0.9 represent strong agreement, and 0.9 to 1.0 represent very strong agreement. Results are reported as (average ± standard deviation) unless otherwise noted.

RESULTS SECTION: CMC values for the ankle were 0.92 ± 0.054, 0.75 ± 0.14, and 0.79 ± 0.09 for the squat, heel-raise, and countermovement, respectively. CMC values for the knee were 0.99 ± 0.004, 0.47 ± 0.35, and 0.90 ± 0.047 for the squat, heel-raise, and countermovement, respectively. CMC values for the hip were 0.973 ± 0.02, 0.10 ± 0.046, and 0.92 ± 0.042 for the squat, heel-raise, and countermovement, respectively.

DISCUSSION: Outside of the knee and hip during the heel raise, correlations were classified as either strong or very strong. There was very little movement in either joint during the heel raise, which potentially resulted in low correlation between the two measurements due to marker noise. The markerless tracking was most accurate for the squat movement (Figure 2.) Further disagreement between the two systems may be partially explained by the differences in the 2D environment of the markerless system and the 3D environment of the marker-based system. The markerless motion tracking system was very easy to set up, allowing for high throughput rate among subjects. We estimate that it takes approximately 4-5 minutes to complete a subject collection for markerless collection in comparison to 15-20 minutes for marker-based collection. There is the ability to add additional cameras to the markerless system, which has potential to allow for 3D reconstruction of joint center positions. The findings of this study are promising as these data were collected using a free, intuitive software installed on a built-in webcam on a consumer laptop rather than a specialized, lab-bound system costing ten of thousands of dollars. This presents opportunities to perform high-through put, community situated research studies, and potentially even moving into a "citizen science" model where community members collect their own data for research studies using this simple system.

SIGNIFICANCE/CLINICAL RELEVANCE:
Kinematic is a useful tool for understanding musculoskeletal function among healthy, injured, or other pathological populations. The validation of simple, less expensive markerless motion tracking approaches such as FreeMocap will provide clinicians and musculoskeletal researchers with an important new tool to understand and treat musculoskeletal injury and disease.

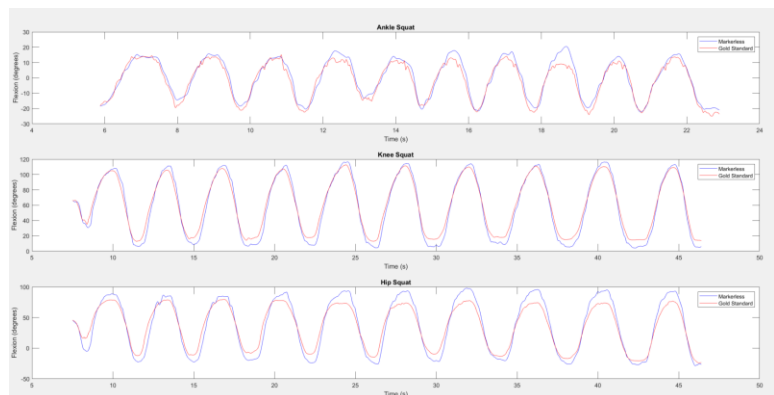IMAGES AND TABLES:

Figure 1: Subject in "A Pose" during markerless motion tracking calibration

Figure 2: Representative Squat Data