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Moving Outside the Lab: Markerless Motion Capture Accurately Quantifies Planar Kinematics During the Vertical Jump

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Introduction

The COVID-19 pandemic has created a need for easy-to- use, socially distanced methods of data collection for biomechanical research. The rise of mature, deep learning software packages provides a unique opportunity for a low cost, socially distant, high fidelity alternative to traditional motion capture. One such example of these software packages is DeepLabCut[1], an open source software developed for pose tracking of laboratory animals. This software has been applied to track human movement, however, there exist concerns about the accuracy of markerless motion capture relative to the marker-based gold standard. The purpose of this study was to evaluate the performance of markerless motion tracking as a method to measure lower limb angles during the vertical jump using a large cohort of subjects from a publicly available data set with time synchronized motion capture and video data.

Methods

Data were compiled from the open data set[2]. The marker-based motion capture data were captured at 120 Hz with a 67-point marker set. Video for markerless tracking was captured on two orthogonal cameras at 30 Hz. We split the data set into a 69 subject training set and a 16 subject test set. To train the model, four people labeled 19 points of interest across 12 frames per subject. Each of these frames were automatically selected via a DeepLabCut clustering algorithm. To test consistency across labelers, a set of five shared subjects were labelled by all four labelers (60 total images). Agreement between labelers was evaluated via the C-1 formulation of the Intraclass Correlation Coefficient (ICC). The data consisted of each of the subjects performing 20 actions. Researchers identified the start and end times of each instance of the subjects' vertical jump and added a one second buffer period to each end of this period. Vertical jump was chosen for further analysis because of its relevance as a common test in sports performance testing. Hip, ankle, and knee angles were extracted from the 1-3 vertical jumps that each subjects performed. The markerless results were compared with the traditional motion tracking results using root mean squared error in addition to coefficient of multiple correlation (CMC) metrics. For both ICC and CMC measurements, r values above 0.9 indicate "very strong agreement."

Results and Discussion

The level of agreement between labelers was very high across the five shared subjects, with an ICC $= 0.998$ and RMSE $= 4.52$ pixels. Results generated from CMC across the whole movement showed very strong agreement between the markerless approach and the traditional motion capture data with a CMC < 0.991 and a RMSE $< 3.22°$. Across the hip, knee, and ankle angles extracted, the CMC values were similarly high, being 0.970 ± 0.055, 0.963 ± 0.471, and 0.853 ± 0.23 respectively (Figure 1).

The results of the study show that free, easy-to-use, open source markerless tracking is a viable alternative to traditional motion capture technology, especially for data collection outside of traditional laboratory spaces. As the CMC values all indicate strong to very strong agreement between the two methods of motion tracking, this represents a significant development in increasing accessibility to accurate motion tracking technology for human subject research. These findings provide evidence that basic cameras can be used to collect human kinematic data remotely without the need for specialized equipment which provides researchers with the ability to reach historically underrepresented groups that are less likely to participate in studies that take place in a laboratory.

Significance

Markerless motion capture has potential – like other devices including mobile dynamometry, instrumented insoles, tensiometers, and inertial measurement units – to transform biomechanical research away from traditional laboratory settings into venues convenient to populations that are under sampled with present approaches without sacrificing measurement fidelity.

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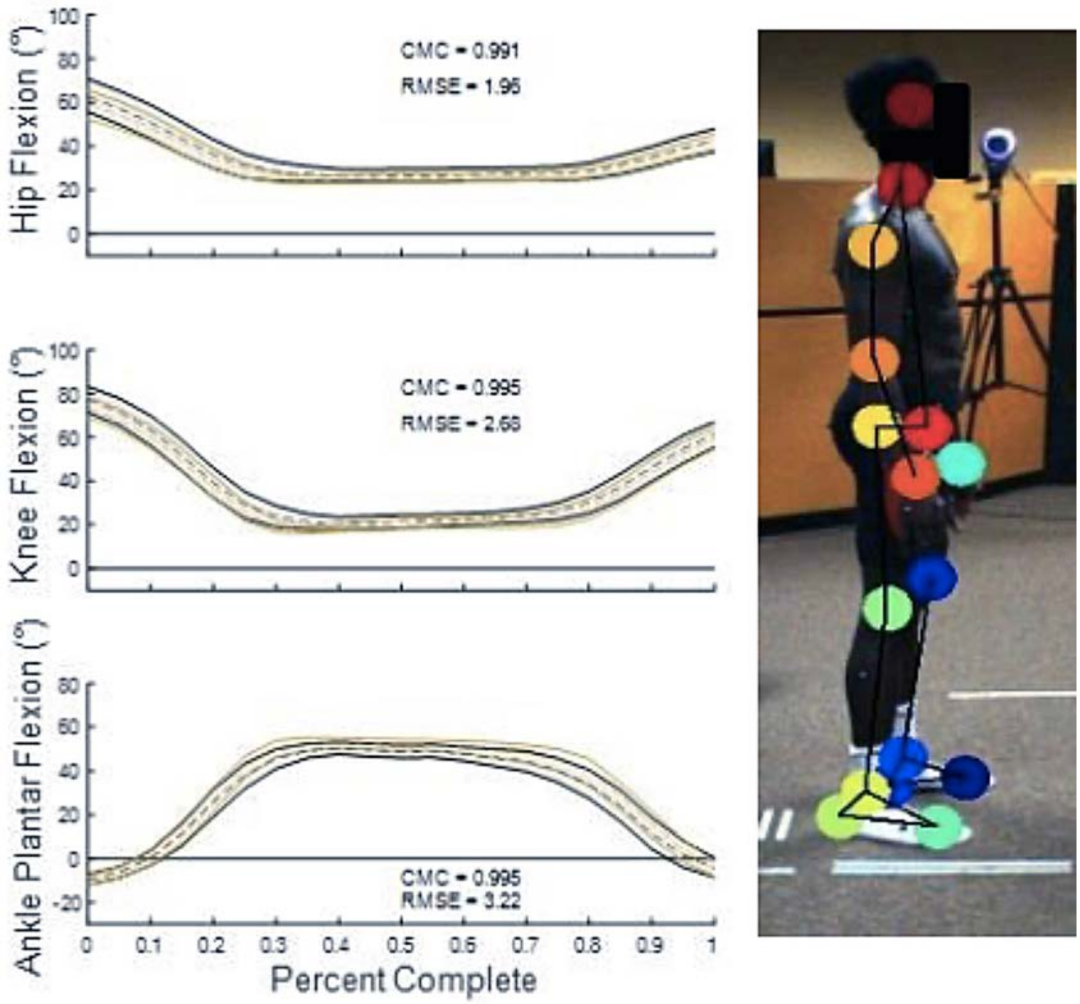

Figure 1. (Left) Gold-motion capture, Black-markerless motion tracking. Dashed-means across all subjects and solid-95% confidence intervals. **(Right)** example of tracked frame.

References

1. Mathis, MW. *Nat Neurosci.* 2018;21:1281-1289.
2. Ghorbani, S. *ArXiv,* 2020.