# THE EFFICACY OF VIDEO-BASED MARKER-LESS TRACKING SYSTEM IN GAIT ANALYSIS

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An alternative to the 3D motion capture is the marker-less 3D video tracking system. Though not rigorously tested yet, the 3D marker-less video tracker would break new grounds if it is possible of extracting similar kinematic parameters as the gold standard 3D marker based motion capturers. The aim of our study is to explore the feasibility of a video based marker-less system. A series of gait analysis tests were carried out on ten subjects with a marker and marker-less system simultaneously. The study suggests potential applications in gait analysis in the academic classrooms and clinical settings where observations of anatomical motions provide meaningful feedback.

**KEY WORDS:** marker-less, motion-capture, gait, three-dimension, biomechanics

**INTRODUCTION:** Gait analysis is an effective tool in the clinical decision making process for improving treatment outcome in an individual particularly with respect to lower limb injuries (Areblad, Nigg, Ekstrand, Olsson, & Ekström, 1990; Engsberg et al., 2007). Such analyses typically require relevant information such as foot pronation, tibia rotation and multiple-joints coordination to be augmented to the user simultaneously with real scenes captured by imaging equipment. This is often captured using high-speed motion capture systems. However, existing motion capture systems are arguable expensive and bulky, requiring practically at least 6 precision proprietary cameras and these are mainly installed in specialised institutions. Consequently, a large proportion of the population seeking medical consultations for such injuries at polyclinics and neighbourhood doctors will not have immediate direct access to the equipment. The alternative to this would be to develop a marker-less tracking system that is not only precise and accurate, but also less expensive and user friendly. Recently, Republic Polytechnic have developed a video-based marker-less tracking system (Star Tracker 3D). This camera system could provide intuitive and observable results for doctors allowing them to remotely diagnosis for the convenience of mainstream patients without the need to use high-speed motion capture systems. However, this system has not yet been evaluated. Thus, the aim of this study was to investigate the efficacy of a video based marker-less Star Tracker 3D system. It was hypothesised that data obtained from Star Tracker 3D would be significantly different from existing motion capture systems rendering it to be not as reliable and accurate as the existing industry's marker based gold standard motion capturing systems.

**METHODS:** Ethical approvals were obtained from the Republic Polytechnic human research ethics committee. A total of ten male subjects aged nineteen to twenty six participated in this study. On the actual day of testing, all subjects were healthy and not suffering from any lower limb musculoskeletal injuries. Both written and informed consent were provided to and obtained from all subjects prior to data collection.

Eight Eagle-4 MAC high-speed motion cameras (Motion Analysis Corp., Santa Rosa, CA) were placed around the motorized treadmill (H/P Cosmos Gaitway II S, Germany). Two Point Grey cameras (GS2-FW-14S5C, Canada) were also placed at pre-selected positions ensuring both cameras focusing on the same point in 3D space. The sampling frequencies for both high-speed and Point Grey cameras were set at 100 Hz and 25 Hz respectively.

Retro-reflective markers sets were placed on the thigh, tibia and foot. Placements of markers were in accordance with Dierks & Davis (2007). All subjects were instructed to walk on the treadmill at their self-selected speed for approximately 8 minutes (Lavcanska et al., 2005). Kinematic data were collected for final 30 seconds during the 8th minute and data collected from the first three consecutive complete strides during the 8th minute were used for final analysis. All data collected were normalized for 100% stance.

The translational and angular excursions for the foot, tibia and thigh segmental movements were derived using the two different systems. A paired t-test was performed to determine the significant differences between the two systems in terms of the excursion values. The alpha value was set at 0.05.

**RESULTS:** Angular and translational data showed similar trends throughout the time history patterns between the two different systems (Figure 1). Statistical analysis revealed significant difference in angular data ($p<0.05$) but not for translational data ($p>0.05$) between the Star Tracker 3D System and high-speed motion capture systems (MAC) (Table 1 and Table 2).

**Table 1**

**Translational excursion data, derived from the Star Tracker 3D (ST3D) and High-Speed Motion Capture (MAC) systems, for the foot, tibia and thigh in the anterior/posterior (Ant/Post), medial/lateral (Lat/Med), and superior/inferior (Sup/Inf) directions. The Mean (standard deviation) values were computed together with the P-values obtained from the t-test performed to compare between the excursion values of the 2 systems.**

| | Foot | | | Tibia | | | Thigh | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ant/ Post | Lat/ Med (cm) | Sup/Inf | Ant/ Post | Lat/ Med (cm) | Sup/Inf | Ant/ Post | Lat/ Med (cm) | Sup/Inf |
| ST3D | 39.5 (4.6) | 9.6 (2.8) | 3.2 (0.7) | 50.1 (3.4) | 7.3 (1.8) | 8.4 (1.4) | 20.1 (0.9) | 9.3 (0.8) | 8.1 (1.6) |
| MAC | 35.1 (2.2) | 6.9 (1.1) | 2.3 (0.2) | 48.5 (1.2) | 8.9 (1.0) | 5.9 (0.9) | 22.0 (0.3) | 6.9 (0.3) | 5.9 (0.1) |
| P value | 0.08 | 0.05 | 0.06 | 0.10 | 0.09 | 0.05 | 0.11 | 0.05 | 0.06 |

**Table 2**

**Angular excursion data, derived from the Star Tracker 3D (ST3D) and High-Speed Motion Capture (MAC) systems for the foot, tibia and thigh in the frontal (Front), sagittal (Sag) and transverse (Trans) planes. The mean (standard deviation) values were computed together with the P-values obtained from the t-test performed to compare between the excursion values of the 2 systems.**

| | Foot | | | Tibia | | | Thigh | | |
|---|---|---|---|---|---|---|---|---|---|
| | Front | Sag (°) | Trans | Front | Sag (°) | Trans | Front | Sag (°) | Trans |
| ST3D | 6.8 (2.1) | 35.2 (4.2) | 3.3 (0.2) | 6.8 (1.0) | 55.9 (8.1) | 5.6 (0.4) | 8.3 (0.8) | 27.8 (2.4) | 11.1 (1.4) |
| MAC | 9.0 (2.3) | 31.2 (2.0) | 2.4 (0.1) | 8.2 (0.8) | 53.4 (3.3) | 4.3 (0.3) | 10.3 (1.1) | 30.1 (3.9) | 8.3 (1.8) |
| P value | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 |

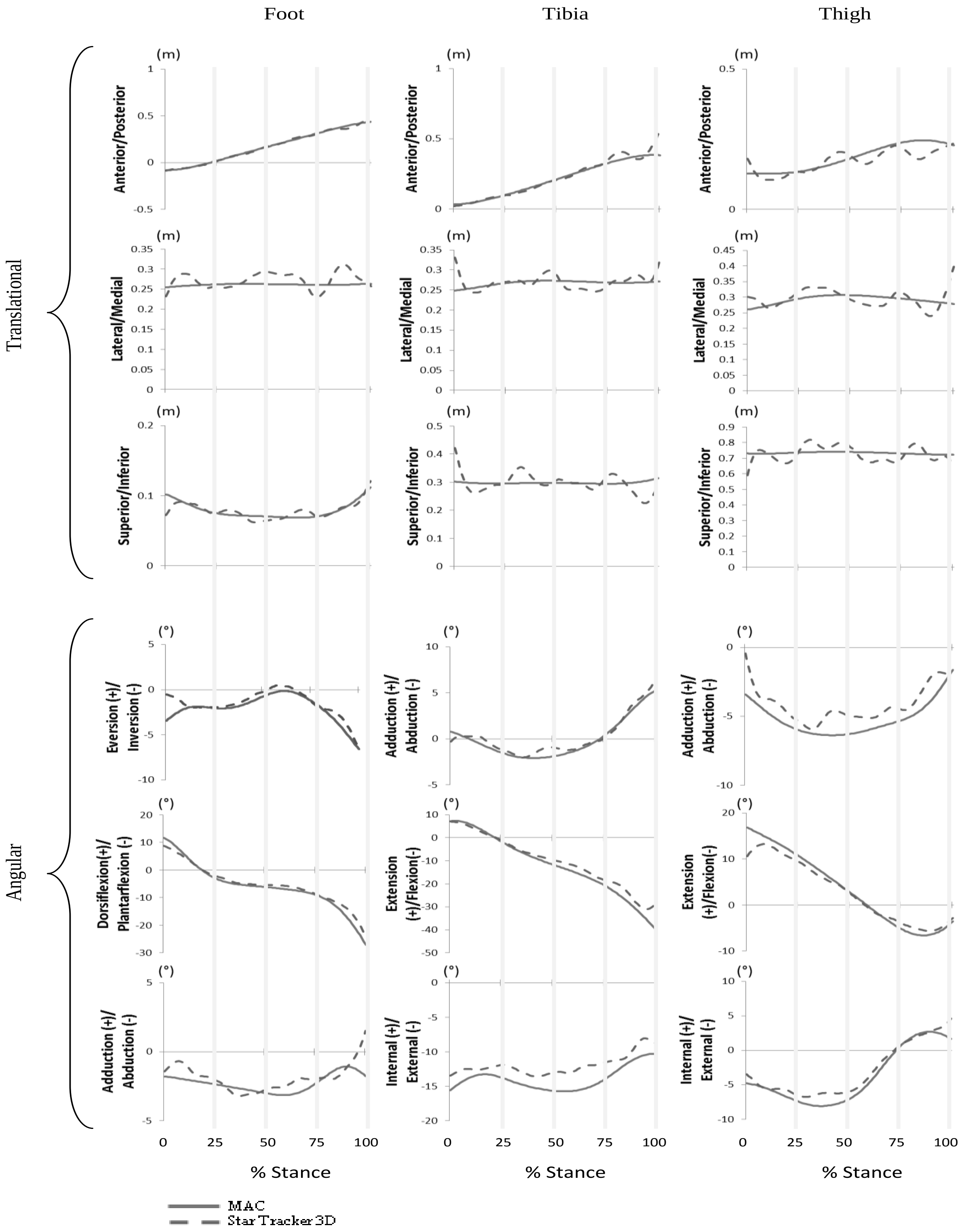


**Figure 1: Ensemble average time history pattern of translational and angular excursion between marker-less (Star Tracker 3D) Tracker and High-Speed motion capture (MAC) systems. The horizontal axes represent the percentage of the stance phase.**

**DISCUSSION:** Despite showing similar trends throughout the normalized time for all the three segments (Figure 1), statistical analysis revealed significant differences in angular data between the two systems (Table 2). As there were no significant difference found in the translational data, we had to reject the null hypothesis that the data obtained from Star

Tracker 3D would be significantly different to existing motion capture systems. Considering that translational data was used to calculate angular data, one possible reason for this may be attributed to blur motion artefacts when using the lower resolution Point Grey cameras. This, according to Ting & Peng (2010), may inhibit the camera's ability to accurately pint-point accurately the centroid of the markers and their location in 3D space. Unlike high-speed motion capture cameras that use optical lights reflected by the markers to distinguish marker positions in 3D space by contrasting against non-reflected surfaces, the low-resolution camera depends on image resolution to determine as such. Should this be blurred, accurate information required for the 3D computations may be missing, thereby affecting the system's ability to accurately determine this.

Another reason may be attributed to differences in sampling frequencies. When compared to high-speed cameras, the Point Grey cameras captured data at 25 Hz. Such lower sampling frequencies may have prevented the low resolution cameras from capturing as many data even when normalised to 100% time frame. One way to overcome this may be to increase the number of cameras that is of higher resolution sensors and with faster sampling rate amongst others when capturing angular data using the 3D star tacker system.

A reliable translational data, nevertheless, suggests potential applications of the 3D star Tracker system for gait analysis in clinical settings and the academic classrooms where observations of anatomical motions could provide meaningful feedback. For example, observing differences in gait patterns between injured and non-injured patients without the need to use high-speed motion capture systems which are often expensive would provide practitioners and educators the ability instantaneously gather feedback on gait characteristics. When used in commercial footwear retail shops, the Star Tracker 3D system could supplement the current method of assessing foot morphology qualitatively by providing insights to pronation or supination of the foot as one walks which otherwise, in the past, would require the use of the more expensive and complex high-speed optical cameras.

**CONCLUSION:** Similar time-history patterns for translational data and insignificant difference in translational data suggest that the Star Tracker 3D System may be a feasible system to capture translational data rendering it as reliable as existing motion capturing systems. Although similar in time-history patterns, significant differences in angular data between systems may suggest that the system has potential in gait analysis in clinical settings and the academic classrooms where observations of anatomical motions could provide meaningful visual feedback and not for a more detailed and accurate quantitative measurements which can be done using existing optical cameras.

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