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Short communication

Validation of a method to accurately correct anterior superior iliac spine marker occlusion

Joshua T. Hoffman [a,*], Michael P. McNally [a,b,c], Samuel C. Wordeman [a,d], Timothy E. Hewett [a,b,c,d,e]

[a] Sports Health and Performance Institute (SHPI) OSU Sports Medicine, The Ohio State University, 2050 Kenny Rd, Suite 3100, Columbus, OH 43221, USA
[b] Department of Orthopaedics, The Ohio State University, Columbus, OH, USA
[c] School of Health and Rehabilitative Sciences, The Ohio State University, Columbus, OH, USA
[d] Department of Biodmedical Engineering, The Ohio State University, Columbus, OH, USA
[e] Department of Physiology and Cellular Biology and Family Medicine, The Ohio State University, Columbus, OH, USA

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ABSTRACT

Anterior superior iliac spine (ASIS) marker occlusion commonly occurs during three-dimensional (3-D) motion capture of dynamic tasks with deep hip flexion. The purpose of this study was to validate a universal technique to correct ASIS occlusion. 420 ms of bilateral ASIS marker occlusion was simulated in fourteen drop vertical jump (DVJ) trials ($n=14$). Kinematic and kinetic hip data calculated for pelvic segments based on iliac crest (IC) marker and virtual ASIS (produced by our algorithm and a commercial virtual join) trajectories were compared to true ASIS marker tracking data. Root mean squared errors (RMSEs; mean ± standard deviation) and intra-class correlations (ICCs) between pelvic tracking based on virtual ASIS trajectories filled by our algorithm and true ASIS position were 2.3 ± 0.9° (ICC=0.982) flexion/extension, 0.8 ± 0.2° (ICC=0.954) abduction/adduction for hip angles, and 0.40 ± 0.17 N m (ICC=1.000) and 1.05 ± 0.36 N m (ICC=0.998) for sagittal and frontal plane moments. RMSEs for IC pelvic tracking were 6.9 ± 1.8° (ICC=0.888) flexion/extension, 0.8 ± 0.3° (ICC=0.949) abduction/adduction for hip angles, and 0.31 ± 0.13 N m (ICC=1.00) and 1.48 ± 0.69 N m (ICC=0.996) for sagittal and frontal plane moments. Finally, the commercially-available virtual join demonstrated RMSEs of 4.4 ± 1.5° (ICC=0.945) flexion/extension, 0.7 ± 0.2° (ICC=0.972) abduction/adduction for hip angles, and 0.97 ± 0.62 N m (ICC=1.000) and 1.49 ± 0.67 N m (ICC=0.996) for sagittal and frontal plane moments. The presented algorithm exceeded the *a priori* ICC cutoff of 0.95 for excellent validity and is an acceptable tracking alternative. While ICCs for the commercially available virtual join did not exhibit excellent correlation, good validity was observed for all kinematics and kinetics. IC marker pelvic tracking is not a valid alternative.

1. Introduction

Retro-reflective markers placed at the anterior superior iliac spine (ASIS) to model and track the pelvis during human movement motion analysis are commonly obstructed by upper extremities or subcutaneous tissue (McClelland et al., 2010). While alternative solutions, such as tracking the pelvis with anatomic iliac crest (IC) markers or computer-generated virtual ASIS marker trajectories exist, these methods are not validated. The purpose of this study was to validate an algorithm that accurately reconstructs occluded ASIS marker trajectories. Hip kinematics and kinetics were compared for pelvic tracking with virtual ASIS markers created by our algorithm, a commercially available function, and using IC markers.

2. Methods

2.1. Study design

2.1.1. Validation of ASIS Virtual Fill algorithm

Fourteen ($n=14$) DVJ trials with complete left and right ASIS, left and right IC, and sacrum (SAC) marker trajectories were selected to validate the algorithm (Hewett et al., 2005). Motion data was collected at 240 samples/s using a 12 camera motion analysis system (Raptor-12 cameras, Motion Analysis Corp, Santa Rosa, CA), with a three-dimensional (3-D) residual error of <0.50 mm. Retro-reflective markers were adhered to the skin with double-sided tape using a modified Cleveland Clinic marker set, which includes markers at both ASIS and IC, and a marker at the L5–S1 joint (Fig. 1). Peak hip flexion was identified using true marker

* Corresponding author. Tel.: +1 614 366 7597.
E-mail address: Joshua.Hoffman@osumc.edu (J.T. Hoffman).

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Table 2
Statistical analysis of hip moments calculated for various pelvic tracking methods. Mean RMSE plus or minus standard deviation and ICC values for moments in the frontal and sagittal plane for all three pelvic tracking methods.

	Moments					
	SHPI Virtual Fill		IC pelvic tracking		Commercial Virtual Fill	
	Sagittal	Frontal	Sagittal	Frontal	Sagittal	Frontal
RMSE	0.40 ± 0.17 N m	1.06 ± 0.36 N m	0.31 ± 0.13 N m	1.48 ± 0.69 N m	0.97 ± 0.62 N m	1.49 ± 0.67 N m
ICC	1.000	0.998	1.000	0.996	1.000	0.996

a valid virtual fill range should be determined that maintains excellent correlation between biomechanical values calculated for virtual and anatomic ASIS markers. This virtual join will also be tested on other commonly obstructed markers.

Conflict of interest statement

None of the authors have actual or potential conflicts of interest related to the work presented in this manuscript.

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