Validity and Reliability of a Markerless Motion Capture System

Anika Weisbrod[1], Richard A. Brindle[2], Eric J. Hegedus[2], Kevin R. Ford[2]
[1]Department of Exercise Science, High Point University, High Point, NC, USA
[2]Department of Physical Therapy, High Point University, High Point, NC, USA
Email: aweisbro@highpoint.edu

Summary

The purpose of this study was to determine the validity and reliability of a clinic-based treadmill with integrated markerless motion capture. Hip and knee angular measures had moderate to high between-day reliability. However, caution should be exhibited interpreting joint angles from this clinic-based motion system as disagreement existed between the gold standard measure.

Introduction

Marker-based motion capture systems (MB) are considered the gold standard for measuring human movement. However, MBs are not widely used due to their operating cost and difficulty. Markerless motion capture systems (ML) are less expensive and easier to use than MB and may be a valid tool to measure human movement in three dimensions. The purpose of this study was to determine the validity and reliability of a ML.

Methods

Thirteen runners participated in the study, 8 males (1.78 ±0.05m; 70.5 ±8.0kg; 18 ±1 year) and 5 females (1.66 ±0.05m; 56.4 ±6.5kg; 19 ±1 year). Each gave their written informed consent before testing. Participants wore standardized neutral running footwear during testing. Prior to the MB data collection, participants were instrumented with retro-reflective markers on their trunk, pelvis, legs and arms. One 30s trial was recorded while participants ran at 3.35m·s^{-1} on a treadmill in the MB capture volume. Another 30s trial was recorded at the same speed on a treadmill attached to a ML. Eleven participants returned to the laboratory at least 7 days later and repeated the ML data collection. Maximum and minimum angles, and range of motion (ROM) for frontal plane (FP) trunk, and sagittal plane (SP) trunk, hips, and knees were generated automatically by the ML. MB data were processed to replicate joint definitions used by the ML for analysis. Only right limb data were analysed. Between-day reliability of the ML was assessed with $ICC_{(1,k)}$. Agreement between the ML and MB was assessed with $ICC_{(2,k)}$ and paired t-tests. ICCs were only considered valid if they had a 95% confidence interval greater than zero and a significant F-test ($p<0.05$) [1]. Trunk, hip, and knee angles from the ML were valid when $p > 0.05$ and $ICC_{(2,k)} > 0.5$.

Results and Discussion

In the FP, trunk ROM ($ICC_{(1,1)}$: 0.56), peak maximum ($ICC_{(1,1)}$: 0.53) and peak minimum ($ICC_{(1,1)}$: 0.74) angles had moderate reliability. In the SP, reliability was moderate for trunk peak flexion ($ICC_{(1,1)}$: 0.67) and extension ($ICC_{(1,1)}$: 0.64) angles, while the ICC for trunk ROM was invalid ($ICC_{(1,1)}$: 0.11; p=0.36). There was good reliability for SP hip ROM ($ICC_{(1,k)}$: 0.85), flexion ($ICC_{(1,k)}$: 0.90) and extension ($ICC_{(1,k)}$: 0.91) angles, as well as SP knee ROM ($ICC_{(1,k)}$: 0.85), flexion ($ICC_{(1,k)}$: 0.86) and extension ($ICC_{(1,k)}$: 0.82) angles. A moderate level of agreement existed between MB and ML in trunk flexion, hip flexion, and knee flexion angles (Table 1). Additionally, there was good agreement between the MB and ML for SP hip ROM, and hip and knee extension angles. However, there was a lack of agreement between the ML and MB for most trunk angles and SP knee ROM indicated by an invalid $ICC_{(2,k)}$. Only FP trunk maximum and minimum, SP trunk flexion, hip flexion, and knee extension angles were similar between MB and ML ($p>0.05$).

The between-day reliability of the ML was similar to the between-day reliability of MB for FP trunk and SP hip and knee angles during running [2,3]. The low variability in trunk angles may have contributed to lower reliability between-days and agreement between systems.

Conclusions

While angular position measured by the ML had moderate to good between-day reliability, only trunk flexion, hip flexion, and knee extension angles were considered valid. ML could be a cost-efficient and user-friendly alternative to MB for tracking changes in running form over time, however caution should be exhibited interpreting joint angles from this ML.

References

[1] Portney LG, Watkins MP. (2009). *Foundations of Clinical Research;* Pearson Prentice Hall.
[2] Doma K et al. (2012). *Int. J. Sports Med.*, **33**: 364-369.
[3] Ferber R et al. (2002). *J. Orthop. Res.*, **20**: 1139-1145.

Table 1: Trunk, hip, and knee angular positions during running, and validity ICCs and paired t-test p-values.

	Trunk Frontal Plane			Trunk Sagittal Plane			Hip Sagittal Plane			Knee Sagittal Plane		
	ROM	Max	Min	ROM	Flex	Ext	ROM	Flex	Ext	ROM	Flex	Ext
ML	9.7 (3.4)	5.4* (2.1)	-4.3* (1.8)	7.0 (1.3)	13.5* (3.9)	6.4 (3.4)	66.2 (8.2)	37.7* (8.1)	-28.5 (4.7)	93.5 (12.8)	100.3 (11.8)	6.8* (4.0)
MB	12.4 (3.0)	6.6* (1.9)	-5.8* (2.9)	15.7 (2.7)	15.7* (5.6)	0.0 (6.6)	60.2 (5.9)	38.0* (5.3)	-22.2 (4.5)	100.4 (9.8)	108.4 (7.2)	8.0* (4.9)
$ICC_{(2,k)}$	0.17#	-0.04#	0.38#	0.20#	0.59	0.53#	0.79	0.73	0.93	0.68#	0.71	0.75
t-test	$p = 0.03$	$p = 0.14$	$p = 0.07$	$p < 0.01$	$p = 0.10$	$p < 0.01$	$p < 0.01$	$p = 0.89$	$p < 0.01$	$p = 0.05$	$p = 0.01$	$p = 0.28$

** = $p > 0.05$; # = invalid ICC; Markerless (ML) and marker-based (MB) mean and standard deviation in degrees for each variable.*