COMPARISON OF TWO ALTERNATE METHODS FOR TRACKING TOE TRAJECTORY

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INTRODUCTION

Toe trajectory during the swing phase of locomotion has been identified as a precise motor control task (Karst, et al., 1999). The standard method for tracking toe trajectory is to place a marker on the superior aspect of the distal end of the 2nd toe itself (Karst, et al., 1999; Winter, 1992). However, others have based their toe trajectory results either on a marker positioned on the lateral aspect of the 5th metatarsal head (Dingwell, et al., 1999; Osaki, et al., 2007), or on a "virtual" toe marker – computed at the anterior tip of the second toe based on the positions of other "real" foot markers (Miller, et al., 2006). While these methods for tracking the toe may seem similar, their results may not be directly comparable. The purpose of this study was to compute toe trajectory parameters using a 5th metatarsal marker and a virtual toe marker, and compare their results with those of the standard toe marker.

METHODS

Twelve subjects gave informed consent and participated in this study, and the NASA-JSC Committee for the Protection of Human Subjects approved the protocol. Subjects wore lab-supplied shoes (Converse, North Andover, MA) with footswitches (Motion Lab Systems, Baton Rouge, LA) affixed to the soles. Three-dimensional motion of the subject's right leg and shoe was recorded using a video-based motion capture system (Motion Analysis, Santa Rosa, CA). Specifically, foot markers were placed on the top surface of the shoe over the end of the 2nd toe (rtoe), the lateral aspect of the shoe at the 5th metatarsal head (mth5), the lateral surface of the shoe at the calcaneus, and the top surface of the shoe at the site of the navicular bone. The virtual marker (vtoe) was computed during post-processing based on the positions of the mth5, calcaneal, and navicular foot markers. The location of vtoe was set at the distal end of the shoe at the second toe, at the same height on the shoe as mth5. In other words, when the foot was flat on the walking surface, vtoe(z) = mth5(z).

Subjects walked on a treadmill for ten 60-second trials per the protocol outlined in Miller, et al. (2006). The marker positions and footswitch data were analyzed using in-house Matlab scripts (Mathworks, Inc., Natick, MA) to determine gait cycle events, kinematics of the foot, and the position of vtoe. The vertical heights of each "toe" marker were reported relative to their respective heights during a quiet stance (static) trial for reference. The analysis concentrated on three features of each toe marker: minimum vertical clearance (TCl), the first peak in early swing (Toemax1) and the second toe peak just before heel contact (Toemax2). Vertical height, %GC, and the ankle and foot flex/extension angles were

calculated at the TCl, Toemax1 and Toemax2 events. A regression analysis was performed on the vtoe and mth5 results versus rtoe (the standard) individually. If vtoe or mth5 results were analogous to rtoe, then the regression lines would have a slope equal to one and an intercept equal to zero.

RESULTS AND DISCUSSION

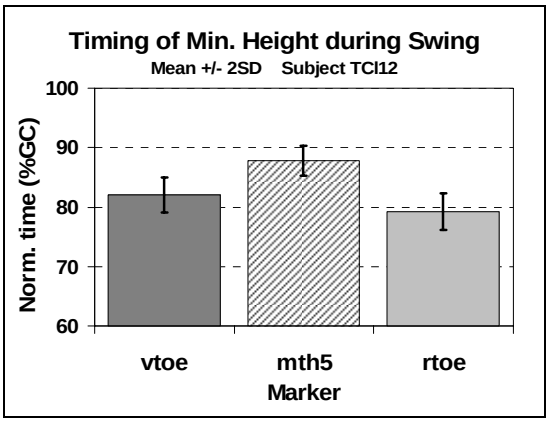

Figure 1: Average gait cycle timing of minimum TCl during swing phase for a representative subject.

The point of minimum mth5 marker height during swing occurred later than for vtoe and rtoe (Figure 1). This overestimation with the mth5 marker could result in a misinterpretation of a subject's true propensity to trip: the foot would be farther anterior of the stance leg – well past the most dangerous point during swing where floor contact would result in a fall (Winter, 1992).

The TCl results for mth5 did not correlate well with rtoe (Table 1), as shown by diminished slopes, and intercepts much different than zero. The results for vtoe showed good agreement, especially for minimum height. Similar results were seen for the ankle and foot angle data for TCl and all Toemax1 parameters. Both markers correlated well with rtoe for Toemax2 parameters.

SUMMARY

The virtual toe marker (vtoe) appeared to be a better analog to rtoe than mth5 for tracking toe trajectory. The virtual marker would be a good alternative in protocols where using a standard toe marker would be impractical.

REFERENCES

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Table 1: Linear regression slopes and intercepts for toe clearance values and normalized gait-cycle timing using vtoe and mth5 markers when compared to rtoe (standard).

		vtoe vs. rtoe		mth5 vs. rtoe	
		Height	**Timing**	**Height**	**Timing**
TCl	**Slope (m)**	0.801	0.659	-0.004	0.391
	Intercept (b)	-6.84 mm	29.9 %GC	20.08 mm	56.9 %GC
Toemax1	**Slope (m)**	0.505	0.845	-0.111	0.771
	Intercept (b)	7.93 mm	9.7 %GC	113.5 mm	14.5 %GC
Toemax2	**Slope (m)**	1.100	0.999	0.729	1.118
	Intercept (b)	-8.06 mm	0.2 %GC	-20.0 mm	-11.8 %GC