DETECTING GAIT EVENTS IN RUNNING FROM KINEMATIC DATA

Christian Maiwald, Thorsten Sterzing, Tobias A. Mayer and Thomas L. Milani
Department of Human Locomotion, Chemnitz University of Technology, Chemnitz, Germany
email: christian.maiwald@phil.tu-chemnitz.de, web: http://www.tu-chemnitz.de

INTRODUCTION

Determining touchdown (TD) and takeoff (TO) is an essential part of gait analysis protocols and is usually accomplished using force plate data and thresholds for ground reaction forces (GRF). It has been proposed that gait events can also be predicted from kinematic data [1-3].

Out of the three different routines which have been published (Hreljac-Marshall Algorithm (HMA) [1], Hreljac-Stergiou Algorithm (HSA) [2], Foot Velocity Algorithm (FVA) [3]), only HSA has been specified for application in running protocols. In an attempt to combine promising aspects of these algorithms but keep the computation procedures and markerset simple, we developed a modified gait event algorithm (GEA) for use in running setups and with various types of footwear. The aim of the present study was to evaluate the accuracy of HMA, HSA, and FVA and to compare prediction errors for TD and TO to the newly developed algorithm GEA. It was hypothesized that prediction errors of GEA are independent from different types of footwear used.

METHODS

40 male subjects performed 12 valid running trials (6 for each leg) in 3 different running shoes across a force-platform (Kistler 9287BA, 960 Hz). True TD and TO events were initially determined from force plate data. Lower extremity kinematics were recorded simultaneously (11 Vicon MX3-cameras, 240Hz). Kinematic data were interpolated to match the force plate sampling rate and low-pass filtered at 50 Hz to enable the meaningful calculation of derivatives using finite difference equations. Table 1 contains brief descriptions of the algorithm procedures. Prediction accuracy of TD and TO was expressed by calculating absolute errors (E_{ABS}) between the true and predicted event-times and giving descriptive statistics (mean, sd) for the distributions of E_{ABS} for all algorithms and types of footwear used.

RESULTS AND DISCUSSION

Table 2 provides mean E_{ABS} (SD E_{ABS}) for all algorithms for each shoe condition. Substantial differences in prediction accuracy can be observed between algorithms, but not between different types of running footwear. SD E_{ABS} indicates that systematic errors were produced by HMA (TO), HSA (TD & TO) and FVA (TO). For HSA, mean E_{ABS} was found to be substantially larger than previously published [2].

CONCLUSIONS

Algorithms which predict gait events from vertical acceleration or position data performed better and more consistently than velocity or angular based concepts in the present study. Only GEA produced acceptable results for predicting TO, and is therefore recommended when analyzing running patterns. Algorithm performance appears to be unrelated to slight variations in marker placement on different types of running footwear. Hence, future work should focus on assessing the suitability of GEA for barefoot or treadmill running protocols and further enhancing its general usability.

ACKNOWLEDGEMENTS

This research was supported by Puma AG, Germany.

REFERENCES

1. Hreljac A et al., *J Biomech* **33**. 783-786, 2000.
2. Hreljac A et al., *Med Biol Eng Comput* **38**. 503-506, 2000.
3. O’Connor et al., *Gait Posture* **25**. 469-474, 2007.

Table 1: Description of algorithm procedures

Algorithm	Procedure to predict TD	Procedure to predict TO
HMA	peak vertical acceleration of heel marker	peak horizontal acceleration of lateral forefoot marker
HSA	minimum angular acceleration of foot segment	minimum angular acceleration of shank segment
FVA	minimum velocity of virtual foot center	maximum velocity of virtual foot center
GEA	peak vertical acceleration of heel marker (similar to HMA, but restricted to 150ms-interval)	vertical position minimum ⊕ peak vertical acceleration of toe marker

Table 2: Mean E_{ABS} (SD E_{ABS}) for TD and TO [ms]: positive values indicate that predicted event lags behind true event

	Shoe	HMA	HSA	FVA	GEA
TD	1	1.28 (21.24)	-47.93 (10.74)	5.28 (8.63)	-0.55 (1.05)
	2	2.13 (22.15)	-46.27 (15.87)	4.17 (8.27)	-0.09 (1.93)
	3	2.34 (22.14)	-44.64 (24.44)	3.76 (9.12)	-0.05 (2.01)
TO	1	146.52 (21.20)	-58.37 (18.99)	64.29 (28.80)	0.23 (1.43)
	2	145.37 (20.80)	-57.82 (18.08)	65.04 (28.35)	0.64 (1.63)
	3	147.14 (27.44)	-58.52 (21.56)	63.95 (25.20)	0.41 (1.64)