A method for mechanical crosstalk rejection and running event detection on a 9-force plates instrumented track

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Introduction

Collecting representative data for athletic performance presents challenges. Laboratory settings reduce the sense of competition, while on-field measurements may require bulky devices [1]. The OLYMPIA SmartTrack, featuring a 10-IR camera stereophotogrammetric system (Vantage V5, Vicon Motion Systems Ltd, UK) and 9 force plates (2xBMS400600 and 7xBMS600900, AMTI Technology, Inc., USA), addresses these issues [2]. Despite installing force plates on a customized steel basin embedded in a concrete soil and using independent threaded bars, mechanical crosstalk among plates was observed while running, altering the resultant ground reaction vectors. Two algorithms were proposed to eliminate crosstalk and automatically detect foot-strike (FS) and foot-off (FO) events during running from force-plate data.

Methods

Ground reaction forces were low-pass filtered (Butterworth, 4th-order, 100 Hz) and artificially switched-off when no contact was detected. Contact was determined either looking at vertical component being larger than a 20 N (force plate-based method, PLT) or checking for the projection of the foot markers (one at the rearfoot and one on the foot tip - marker-based method, MKR) on force plates surface. Tentative on-off instants were further refined. Typically, only one contact occurred per platform, with a swing phase lasting approximately 0.10 s. Subsequent contacts within 0.05 s were merged. FS and FO events were automatically identified as instants where the vertical component of the resultant ground reaction force reached 20 N before and after a peak of at least 1200N. The algorithms were tested on three transfemoral amputee female athletes (T63 100 m medallists in 2020 Paralympic Games) wearing different Running Prosthetic Feet over trials and a 3S80 monoaxial prosthetic knee joint (Ottobock, Germany) on their residual limbs. Automatic FS and FO event detection underwent Bland-Altman testing [3] against the manual labelling by an expert operator (GOLD). Correlation analysis was also performed.

Results

Seven running trials per athlete were analysed (stance duration = 0.114±0.022 s), yielding 85 FS and 85 FO events. No residual crosstalk was observed after applying both algorithms. The MKR method returned 2 false negatives for both FS and FO, whereas the PLT had none. Both methods returned 1 false positive for both FS and FO. The operator excluded that specific stride due to unclear foot positioning over the force platform.

Event type	{data1} vs {data2}	Bias	LoA		RC	Pearson's r	slope	intercept	KS-test *p*-value		*t*-test
			Lower	Upper					{data1}	{data2}	*p*-value
FS	**MKR vs GOLD**	-5	-20	10	17	0.9998	0.9973	0.0000	0.658	0.584	< 0.001
	PLT vs GOLD	-6	-13	1	13	1.0000	1.0006	0.0000	0.648	0.575	< 0.001
	PLT vs MKR	-1	-13	12	12	0.9999	1.0026	0.0000	0.671	0.670	0.312
FO	**MKR vs GOLD**	3	-6	12	10	0.9999	0.9978	0.0000	0.748	0.769	< 0.001
	PLT vs GOLD	2	-5	9	8	1.0000	0.9981	0.0000	0.738	0.718	< 0.001
	PLT vs MKR	0	-6	6	6	1.0000	1.0001	0.0000	0.802	0.794	0.277

Table 6. Results of Bland-Altman and correlation analysis for foot-strike (FS) and foot-off (FO) events comparing marker-based (MKR) and force plate-based (PLT) with the GOLD standard and between them: bias, limit of agreement (LoA - with its lower and upper value), the repeatability coefficient (RC), the Pearson's correlation coefficient (r), the slope and the intercept of the linear interpolation between the datasets to compare, the Kolmogorov-Smirnov test p-value for both dataset to compare and the t-test p-value obtained from comparing the datasets.

Discussion

The presented algorithms effectively remove the crosstalk and allow for robust automatic FS and FO events detection while running. Marker-based and force plate-based methods are interchangeable. **Acknowledgments.** Supported by INAIL: agreement n. PR19-PAI-P4.

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