ANKLE FRONTAL PLANE KINEMATICS DETERMINED BY GONIOMETER, GYROMETER AND MOTION ANALYSIS SYSTEM: A MEASUREMENT DEVICE VALIDATION

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INTRODUCTION

Ankle kinematics play an important role in numerous studies investigating biomechanics of walking and running. 3D Motion analysis systems (e.g. Vicon, Qualisys) have become the standard for acquiring lower extremity kinematics. When a 2D frontal plane approach is sufficient, electrogoniometers are considered an easy to use alternative [1]. An innovative way to measure knee joint kinematics is the use of a combination of electrogyrometer and accelerometer [2]. However, heavy impact noise on the foot at touch down has made the use of accelerometers difficult and less practible for ankle kinematics [3]. Therefore, the solely use of a single gyrometer was tested to determine frontal plane ankle kinematics. If motion analysis system, goniometer, and gyrometer may be used interchangeably to determine frontal plane kinematics, it would be possible to pick the most appropriate one for a given study design. However, a validation of these systems has not been published so far. Thus, the purpose of this study was the comparison of frontal plane ankle kinematics measured simultaneously by an electrogoniometer, electrogyrometer, and motion analysis system.

METHODS

19 heel-to-toe runners (26.5 ±2.9years, 77.5 ±4.9kg, 176 ± 5.0 cm) with laboratory experience participated in this study. For each subject five valid trials at 3.5m/s (±0.1) were recorded. Ground reaction forces (GRF) were collected at 1kHz using a force plate (Kistler 9287BA) in the middle of a 13m running track. Frontal plane rearfoot kinematics were recorded simultaneously with the following three devices and synchronized using the vertical GRF:

- Electrogoniometer (GO): attached to heel cap & shank (Megatron MP10 1kΩ, 1kHz)
- Electrogyrometer (GY): fixed to the heel cap beneth goniometer axis (ADXRS610, 1kHz)
- Motion Analysis system (MA): Vicon, 12 MX-3 cameras, 240Hz, Cardan angle XYZ

The motion analysis setup included calibration and tracking marker on shank and foot segments of the right leg. Frontal plane ankle kinematics were compared between all three systems by determining the following discrete parameters: Maximum eversion velocity (EV_{vel}) and maximum eversion excursions (EV_{rom1-3}). EV_{rom1-3} were calculated by subtracting maximum ankle inversion from maximum eversion angles within different time intervals of the braking phase. These time intervals were selected on the basis of anterior-posterior GRF. EV_{rom1} is the maximum excursion from touch down till the first 10^{th} of ground contact, EV_{rom2} till maximum braking phase, and EV_{rom3} till the end of the braking phase. Correlation coefficients were calculated between the parameters of MA (golden standard) and GO, respectively GY. Further information (mean difference (Diff) and 95% confidence interval of the differences between systems ($CI_{95\%}$)) were obtained by analyzing Bland-Altman plots.

RESULTS AND DISCUSSION

GO eversion velocity and excursion parameters correlate highly with MA. The highest correlation is found if the total braking phase is considered for maximum eversion determination (EV_{rom3}).

GY eversion velocity and excursion parameters correlate highly with MA as well. However, best correlations are achieved using the time interval ending at maximum braking force (EV_{rom2}).

GO and GY tend to underrepresent eversion excursion systematically at EV_{rom2} and EV_{rom3} (Diff, Table 1). The variation of the differences between GO and MA does not differ between EVr_{om1} to EV_{rom3}, whereas it increases constantly between GY and MA from EV_{rom1} to EV_{rom3} ($CI_{95\%}$, Table 1).

Since the single gyrometer measured foot rotations only, gyrometer results indicate that ankle eversion occurs mainly in the foot rather than the shank segment.

Table 1: Correlation of eversion parameters determined by GO, GY, and MA (EV_{vel} in °/s, EV_{rom1-3} in °)

		EV_{vel}	EV_{rom1}	EV_{rom2}	EV_{rom3}
MA-GO	r	0.771	0.769	0.888	0.914
	Diff	8.9	0.1	-1.8	-1.5
	$CI_{95\%}$	135.2	2.5	2.6	2.4
MA-GY	r	0.721	0.677	0.736	0.611
	Diff	77.9	1.5	-1.4	-2.2
	$CI_{95\%}$	142.7	2.8	3.9	5.2

CONCLUSIONS

Goniometer parameters show high, gyrometer acceptable correlations to motion analysis data. Therefore, depending on the research question the device most suitable may be used (e.g. gyrometer for mobile outdoor data collection). Furthermore, differences in the results using various time intervals to determine eversion parameters unveil the need for further discussion how to define discrete parameter of ankle frontal plane kinematics.

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