3D MEASUREMENT OF LOWER LIMB KINEMATICS IN ALPINE SKI RACING USING INERTIAL SENSORS

Benedikt Fasel[1], Jörg Spörri[2], Julien Chardonnens[1], Matthias Gilgien[3], Josef Kröll[2], Erich Müller[2] and Kamiar Aminian[1]

[1] Laboratory of Movement Analysis & Measurement, EPFL, Switzerland

[2] Department of Sport Science and Kinesiology, University of Salzburg, Austria

[3] Department of Physical Performance, NSSS, SLF, Norway

KEY WORDS: inertial sensors, wearable system, alpine skiing, lower limb kinematics, validation

INTRODUCTION: In alpine skiing monitoring the 3D segment kinematics is crucial to better understanding the injury risk factors and performance aspects. 3D camcorders have been primarily used to evaluate segment kinematics. While these systems allow valid measurement, their complexity limits their use to research applications. Alternatively, wearable systems fusing inertial measurement units (IMUs) and GPS have been proposed (Supej, 2009). However, further improvements are required for these methods to be routinely useable. This study aimed to design and fully validate a system suitable for daily routine based on IMUs only to measure the lower limb segments orientation in alpine ski racing.

METHOD: Four IMUs (Physilog®, CH) were affixed to both shanks and thighs. Thigh, shank and knee drift-free orientation was computed by devising a method, dedicated to alpine skiing, fusing 3D angular velocities and accelerations (Dejnabadi, 2005). The proposed approach was assessed against a 3D camcorder system monitoring an entire turn (gate 7; 27m distance; 8m offset; 26° incline) of a water-injected GS. 6 athletes agreed to participate and in total 8 turns were recorded. Mean (accuracy) and standard deviation (precision) difference as well as linear correlation was calculated between the times-series of the IMU-based system and camcorder.

RESULTS: The accuracy and precision of the proposed method was below 2° and 6.4°, respectively (Table 1). The angle patterns showed a high agreement between the proposed and camcorder system (Figure 1 and correlation values >0.91 in Table 1). It is worth noting that specific knee flexion angle errors of ~4° were reported for 3D camcorders (Schiefermüller, 2009)

Table 1. Validation results (N=16)

	Accuracy	Precision	Correlation
Shank Inclination	2.0°	5.0°	0.91
Thigh Inclination	1.0°	6.4°	0.95
Knee Flexion	-1.4°	5.5°	0.98

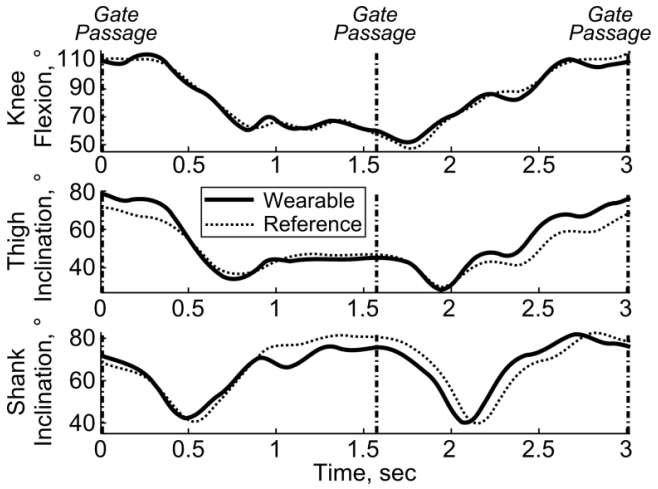

Figure 1. Angle patterns of a typical turn

DISCUSSIONS: Compared to camcorders or devices combining GPS-IMUs, the proposed system was easy-to-handle and not restricted to small capture volume and small number of subjects. This system could easily be extended to other joints (e.g. shoulder) to provide a full picture of the alpine skier's segments kinematics.

REFERENCES

Dejnabadi, H. et al. (2005). IEEE Transactions of Biomedical Engineering, 52, 1478-84.

Supej, M. (2010). Journal of Sports Sciences, 28(7), 759-69

Schiefermüller, C. (2009), PhD Thesis,Salzburg, p. 180.