USING INERTIA MEASUREMENT UNIT (IMU) FOR EXERCISE ANALYSIS.

BORIS JIDOVTSEFF [1] · OLIVIER BRULS[2] · FRANÇOIS TUBEZ[1] · LAETITIA MONFORT[1] ·
NIGEL HARRIS[3] · JOHN B. CRONIN[3] ·

[1] Sport Science Department, University of Liege, Belgium ; [2] Department of Aerospace and Mechanical Engineering, University of Liege, Belgium; [3] Sport Performance Research Institute New Zealand, AUT University, New-Zealand

INTRODUCTION

Motion analysis technology (i.e. videography, optical motion capture, electromyography and force plates) have been utilized by sports scientists in laboratory based environments to assess the kinematics and kinetics of athletic movements (e.g. running, jumping, kicking and throwing) (1). These systems are valid and reliable, but are limited to controlled laboratory settings. Emerging wireless technologies like an inertia measurement unit (IMU) have the capability to assess three-dimensional (3D) athletic movements in the field and weight-room based environments. Wireless 3D technology may allow for accurate assessment of dynamic exercises (i.e. sprinting, jumping, throwing, kicking and squatting) during training and game type situations. These IMU systems are relatively untested in terms of assessing the above movements; therefore must be validated before being utilized in practice. So, the aim of this study was to investigate the utility of an IMU system in term of motion analysis, and the subsequent reliability of the measurements.

METHODS

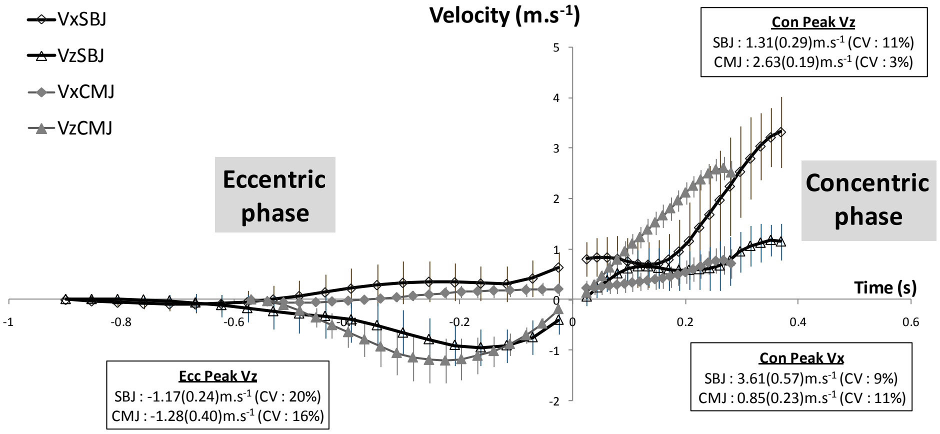
Sixteen healthy subjects (22±3 yr, 1.76±0.12 m, 72±13 kg) participated in this study and were tested twice, one week apart, following the same exercise modalities. After a standardized warm-up and familiarization with movements, they performed ten dynamic exercises allocated in four categories:

1. Vertical jumps: squat jump (SJ), counter movement jump (CMJ), drop jump (DJ) and six continuous jumps (6CJ);
2. Horizontal jumps: standing broad jump (SBJ), 5 alternate bounds (5AB) and 5 hops (5H);
3. Change of direction: quick change of direction (QCD) and distance change of direction (DCD)
4. Twenty meter sprint (SPRINT).

Three trials were undertaken for the “single impulse” exercises and two trials were for the “multi-impulse” exercises. Three minutes recovery occurred between trials and exercises. An inertia movement unit (Inertia Link, Microstrain, USA) was attached to an elastic belt on the subject’s back, close to the center of mass (CM) position. Three axis acceleration and three angle rate signals were recorded at 100 Hz. The signals were thereafter analyzed using customized Exercise Labview Applications (ELA) (Labview 8.5, National Instrument) specifically developed for each exercise. Each ELA had a common part including the orientation matrix that was used to define the device relative orientation. This matrix was essential to obtain vertical (z), lateral (y) and horizontal (x) body acceleration (A), velocity (V), displacement (D) and power (P). For each ELA, a specific program was developed in order to split the exercises into specific parts and to quantify the parameters of interest. In this study, we have specifically focused our analysis on impulse and flight phases. Impulse can be divided into an eccentric phase (CM lowering) and a concentric phase (ascending CM). Classical descriptive statistics were used in the present study. Inter-session reproducibility was measured with a specific coefficient of variation (CV)(2). A dependent t-test was used to determine significant differences.

RESULTS

Using an IMU enables many measurements for each exercise to be quantified. Indeed, peak and average values could be calculated for each variable (A, V, P, D) for the three axes and during the different parts of the movement. Resultant velocity, movement orientation, stride frequency, movement phases duration, reactivity index, stiffness could also be extracted from the IMU. Summarizing all possible measures is beyond the scope of this abstract, but included are a few examples. Figure 1 compares Vx and Vz during SBJ and CMJ. While they are both unweighted leg power tests, they present very different curve shapes with very different peak values, especially in the concentric phase. Differences can also be observed for eccentric and concentric phases duration as well as for CV's.



Con Peak Vz
SBJ : 1.31(0.29)m.s^{-1} (CV : 11%)
CMJ : 2.63(0.19)m.s^{-1} (CV : 3%)

Ecc Peak Vz
SBJ : -1.17(0.24)m.s^{-1} (CV : 20%)
CMJ : -1.28(0.40)m.s^{-1} (CV : 16%)

Con Peak Vx
SBJ : 3.61(0.57)m.s^{-1} (CV : 9%)
CMJ : 0.85(0.23)m.s^{-1} (CV : 11%)

Fig.1 Curve analysis representing the evolution of Vx and Vy during eccentric and concentric phase for SBJ and CMJ. Main peak values and CV are also presented.

Reliability of the IMU system was also investigated, the inter-session reproducibility appeared to be acceptable for phase durations and velocity, especially in the main exercise axis (i.e. Z for CMJ and X for SBJ) with most CV's <10%. Reproducibility was moderate for A (6-30%), moderate to weak for P (7-33%), and weak for D (12-97%). During long duration exercises like SPRINT, 5AB, 5H and 5CJ, we have had frequently observed drift of D, V and P signals. An example is presented in Figure 2.

DISCUSSION

This study confirmed that wireless IMU systems offer very interesting options for the assessment of sport specific movement as they allow 3D motion analysis. Portable and very light, such devices can be used in the field, far from controlled laboratory settings. An amazing amount of analysis is possible with such technology from detailed curve analysis to the computation of average and peak values in three directions. However, inconsistence observed in some results could most likely be attributed to technological weakness that needs to be improved. Most troublesome were; noise from the low sample frequency (100hz), lost data due to the wireless system, orientation error due to gyro saturation and signal drift due to single and double integration.

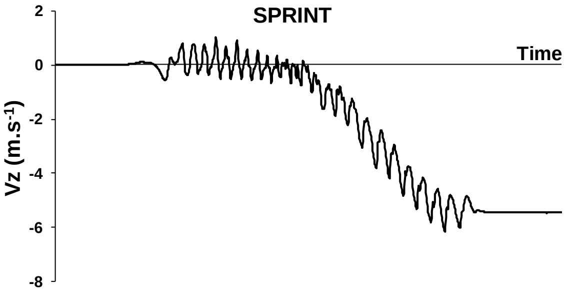


Fig.2 Drift of Vz signal during SPRINT test due to orientation error.

CONCLUSION

The present study confirms the utility of IMU technology in exercise analysis. However, technological improvements are still needed prior to meaningful, accurate and reliable data can be generated.

REFERENCES

[1] Robertson et al., *Research methods in biomechanics* 308p, 2004.
[2] Jidovtseff et al., *Isok Exerc Sci* **14,** 53-62, 2006.