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Inertial sensors in sports: application to vertical jumps

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Countermovement jump (CMJ) height is typically estimated by applying the equation of free-fall to the motion of the centre of mass (CM) during the flight phase. In field setting, this is generally done using optical cells/contact mats. The reliability of the estimate is strongly affected by the subject's expertise in executing the jump. Wearable inertial measurement units (IMU), containing 3D accelerometers and gyroscopes, can provide similar information regardless to execution constraints. However, the interpretation of signals still requires the development of computational techniques and of models embodying the specific motor task. This study aims to verify whether IMU can be used to assess CMJ performance. Twenty-eight college students (67 ± 13 kg, 1.73 ± 0.09 m) performed 5 CMJ, with a 3-min rest in between. A wireless IMU (Sensorize, Italy) was placed using an elastic belt around the trunk at L5 level. Sensor accelerations, influenced by trunk bending, were expressed in a global reference system using the gyroscopes. Flight time (T) was identified when the vertical acceleration (a_z) was lower than gravity. Subsequent numerical integration of a_z provided velocity and height of the centre of mass at take-off. These quantities and the ballistic law of motion were used to estimate jump height (H). A stereophotogrammetric system (Vicon MX, UK) and a force plate (Bertec, USA) were used to obtain reference values for H (Hr) and T (Tr). ANOVA for repeated measurements ($p < 0.05$) and Pearson's correlation coefficient evaluated statistical differences between H and Hr and T and Tr, respectively. Intra-individual reliability was assessed by means of the Intraclass Correlation Coefficient (ICC). IMU and reference values were highly correlated (H: $r = 0.9$; T: $r = 0.9$) and presented no statistical difference for both H and T. Relevant differences were $2 \pm 8\%$ and $4 \pm 3\%$ for H and T, respectively. High intra-subject IMU reliability was found (ICCJ=0.834, ICCT=0.868). This study showed how the combination of a 3D accelerometer and gyroscope can lead to an accurate and repeatable estimate of jump height. CMJ height estimate does not suffer from any assumption about the performed task and it is not affected by the subject's expertise (reliable for elderly and young populations). Furthermore, since the IMU is worn by the athlete, vertical jumps can be performed on any surfaces such as grass, sand, springboards, etc.

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