VALIDATION OF ACCELEROMETER DATA FOR MEASURING IMPACTS DURING JUMPING AND LANDING TASKS

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The purpose of this study was to examine the validity of a commercially-available accelerometer, as used in the field team sports context. Ten adult participants completed two movement tasks: 1) a drop landing task from 30-cm, 40-cm and 50-cm heights [DLAND], and 2) a countermovement jumping task [CMJ]. Peak acceleration values, both smoothed and unsmoothed, occurring in the longitudinal axis [Y] and calculated to produce vector magnitude values [VM], were compared to peak vertical ground reaction force values [VGRF]. All acceleration measures were moderately correlated (r = 0.45 – 0.70), but also significantly higher than weight-adjusted VGRF, for both tasks. Though the raw acceleration measures were mostly above the acceptable limit for error (> 20%), the smoothed data had reduced error margins by comparison, most of which were well below 20%. These results provide some support for the continued use of accelerometer data, particularly when smoothed, to accurately quantify impacts in the field.

KEYWORDS: validation, accelerometers, jumping, impact.

INTRODUCTION: Accelerometers are commonly used as a tool for injury measurement (Brolinson et al. 2006) and assessment of joint loading (van den Bogert et al. 1999). Increasingly, sports scientists are using accelerometry to assess sporting performance and analyze physical demand, particularly in field team sports (Carling et al. 2009). Of particular interest in this environment is the capacity for accelerometers to provide an objective measurement of impact data (i.e., high-intensity movements involving a rapid change in acceleration), which could then be used to aid in the appropriate planning of recovery and training loads (Duthie et al. 2003). Though their use in this context is rapidly growing, few studies have attempted to validate such devices for quantifying sporting movements.

The current literature provides mixed evidence for the accuracy of accelerometers when measuring impact events. Strong correlations (average $r^2 = 0.812$, $p \leq 0.01$) have been observed between peak ground reaction forces (GRF) and peak accelerations measured at the tibia during a countermovement jumping task (Elvin et al. 2007). Additionally, moderate correlations (r = 0.46 to 0.52, $p < 0.001$) have been observed between three different accelerometer models and body weight-adjusted force, measured in children during continuous low-intensity jumping and a drop landing task performed from a 23-cm footstool (Garcia et al. 2004). By contrast, other researchers did not observe a linear relationship between uniaxial accelerometer counts and GRF (r = -0.15, $p > 0.05$), measured during a jumping down task (30.5 cm initial height) (Janz et al. 2003). In addition to the paucity of literature in this area, these studies have limited relevance to the team sports environment.

"Off-the-shelf" devices used in team sports settings often sample data at lower rates (e.g., 100 Hz) than accelerometers used in laboratory settings (3000 Hz) (Zhang et al. 2008). It is not known whether accelerometers sampling at relatively low rates can measure impact events with sufficient accuracy. Though peak impact accelerations are of interest to performance analysts in the field, only one study (Elvin et al. 2007) has examined peak acceleration values (as opposed to acceleration counts or data averaged over time). No studies have placed accelerometers at the base of the neck, or accelerometers that have been integrated with Global Positioning System (GPS) units, both of which are commonly employed in elite sporting environments (Carling et al. 2008). Given these gaps in the literature, the purpose of this study was to examine the validity of a commercially-available GPS-integrated accelerometer, as used in the field team sports context.

METHOD: Ten adults (6 males and 4 females) participated in this study. Participants wore one data-recording triaxial accelerometer, which sampled data at 100 Hz and was embedded within a GPS monitor (SPI Pro, serial no. ASP00725, GPSports Pty Ltd, Australia). The unit was worn in a harness provided by the manufacturer, and orientated such that the Y axis was aligned with the longitudinal axis of the participant. For the criterion measure, vertical ground reaction forces (VGRF) were measured by a portable force plate (model ACG, serial no. 0687, Advanced Mechanical Technologies Inc., USA), sampling at 100 Hz. Post a familiarisation session, participants performed all tasks in one session as follows: (1) drop landing [DLAND] from 30-cm, 40-cm, and 50-cm platforms in a randomized order; and (2) countermovement jumping [CMJ].

Acceleration data for all jumps was downloaded from the monitor using proprietary software (Team AMS version 2.1.05 P2, GPSports Pty Ltd, Australia). A fourth order, zero lag, dual pass, Butterworth digital filter with a cutoff frequency set at 20 Hz was applied to Y axis (Y) and vector magnitude (VM) acceleration histories (Bisseling and Hof 2006). This process was performed in a customised LabView program (National Instruments, USA). Peak acceleration values for both the raw (Y and VM) and smoothed data (Y_s and VM_s) were compared to peak VGRF values, adjusted for body weight (BW). A two-way (measure × task condition) general linear model ANOVA, with Tukey post-hoc test, was used to compare whether the peak acceleration data were significantly different than peak VGRF values. Pearson's r values were calculated to examine the relationship between VGRF and the accelerometer measures. Percent CV difference ($\%Cv_{diff}$), calculated from natural log-transformed data, was used to provide an error measurement; the limit of acceptability was set at 20%. Though it is acknowledged that CV values above 10% are rejected in other fields of research, it has been proposed that this analytical goal is often selected as an arbitrary limit for acceptable variability (Atkinson and Nevill 1998). In consideration of the unconstrained nature of team sports combined with field measurement, 20% was deemed a reasonable and realistic limit of variability for the purposes of this study.

RESULTS: Mean peak Y axis accelerations ranged from 2.24-5.09 *g*, and mean peak vector magnitude values ranged from 2.92-6.04 *g*. Peak weight-adjusted VGRF values ranged from 2.14-4.18 BW. Tukey post-hoc analysis revealed that all peak acceleration values (unsmoothed and smoothed) were significantly higher than VGRF/BW across the tasks. Moderate correlations ($r = 0.45 – 0.70$, $p < 0.05$) were observed between the accelerometer variables and force for all tasks. Most $\%CV_{diff}$ values examining unsmoothed data (Y and VM) were above the acceptable limit of 20%. On the other hand, most $\%CV_{diff}$ values in relation to smoothed data (Y_s and VM_s) were within the acceptable limit. $\%CV_{diff}$ values were lower for CMJ compared to DLAND. Refer to Table I for further details.

DISCUSSION: The use of accelerometers in field team sports is widespread and continues to grow. However, the accuracy of accelerometry for quantifying impact movements in this context is unknown. The results of the present study indicate that, although the raw accelerometer values appear unsuitable as a measure of jumping-based impacts, smoothed accelerometer values can quantify jumping-based impacts with improved accuracy. This is particularly evident in the smaller %CVdiff values (10.9-22.2%), compared to the unsmoothed data (16.8-30.8%). The accuracy of the raw data may have been influenced by monitor placement, and monitor vibration, occurring due to movement within the harness.

Table 1. Accelerometer data compared to vertical ground reaction force data

Task	ANOVA (Main effect of measure)	Pearson r	Percent CV Difference (%)
Comparison to Y axis accelerometer data (Y)			
DLAND	F (4, 745) = 98.0*	0.54*	21.4
CMJ	F (4, 499) = 45.0*	0.49*	16.8
Comparison to vector magnitude (VM) accelerometer data			
DLAND	As above	0.56*	30.8
CMJ		0.45*	22.5
Comparison to Y axis smoothed accelerometer data (Y_S)			
DLAND	As above	0.70*	15.5
CMJ		0.59*	10.9
Comparison to vector magnitude smoothed accelerometer data (VM_S)			
DLAND	As above	0.70*	22.2
CMJ		0.55*	15.9

* Value is statistically significant, $p < 0.05$; DLAND = Drop landing task; CMJ = Countermovement jumping task.

In the existing literature, monitors have been attached to participants at sites within close proximity to the impact site. Both Garcia et al. (2004) and Janz et al. (2003) utilized hip and waist placement sites, as is common practice in physical activity research (Ward et al. 2005). Meanwhile, Elvin et al. (2007) measured tibial axial accelerations by aligning two accelerometers with the fibular heads. It is likely that placement site plays a role in the strength of any linear relationship between impact forces and impact accelerations. It is perhaps unsurprising then, that correlations observed in this study between force and acceleration data were only moderate in strength, given the distance of the monitor (placed at the base of the neck; manufacturer-recommended site) from the impact site at the feet.

It might be expected that accelerations measured at the base of the neck would be lower than the reaction forces experienced on initial ground contact, due to shock attenuation by major body structures (Bennell et al. 1996; Coventry et al. 2006; Lafortune et al. 1996). Previous studies indicate that impact shock experienced at the knee can be attenuated by more than 50% by the time the shockwave passes to the head (Bennell et al. 1996; Coventry et al. 2006). However, the results of the present study showed the opposite outcome, as peak impact accelerations were significantly higher than peak impact VGRF values. This apparently contradictory finding may have several explanations.

The use of accelerometry to measure impacts is based on Newton's Second Law of Motion, which describes a linear relationship between force and acceleration experienced by an object. The data collected for this study was analyzed accordingly, using Pearson's r to examine whether the accelerometer variables correlated with force. However, previous research (Derrick 2004) indicates that there may be dissociation in the theoretically linear relationship between forces and accelerations experienced by the body during impacts, as a result of the segmental nature of human movement. This has been investigated with specific examination of the influence of knee contact angle on the force-acceleration relationship (Derrick 2004; Lafortune et al. 1996). Lafortune and colleagues (1996) observed that, in response to more severe running impacts, knee contact angle increased to improve shock attenuation through the lower limb. This postural change caused a decrease in peak impact forces, but an apparently discordant increase in peak impact accelerations experienced by the legs (Derrick 2004). As it was not measured nor controlled in the present study, it is not known to what extent knee contact angle (and possibly hip angle and upper body movement) may have affected the force-acceleration relationship in this data.

Higher peak accelerations may also be a result of monitor vibration and sensitivity to small shifts in position. Inadequate security of the unit within its pouch may introduce accelerations that are unrelated to the movement events of interest. Further investigation into alternate placement sites and other methods of securing the unit to the athlete is warranted, and may improve the accuracy of the GPS-integrated triaxial accelerometer while ensuring athlete comfort, player safety, and unit accessibility in competition settings.

CONCLUSION: The findings of the present study provide some support for the use of harness-mounted triaxial accelerometers, particularly following data smoothing, to measure jumping impacts, similar to those that occur in field team sports. Further research is recommended into a wider variety of sport-related movements (e.g., running-based impacts), as well as examining the feasibility of different accelerometer placement sites and attachment methods, to minimize monitor vibration.

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