DEVELOPMENT OF A FIELD TESTING PROTOCOL FOR THE BIOMECHANICAL ANALYSIS OF SNOWBOARD JUMP LANDINGS – A PILOT STUDY

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A biomechanical analysis of snowboard jump landings is yet to be published. The purpose of this work was to develop a protocol to allow the collection of meaningful data in a real snowboarding environment. A video calibration technique was developed to provide superior measurement accuracy over a standard central cube calibration. The accuracy of a snowboard mounted force plate was assessed under various loading conditions. It was concluded that its performance was satisfactory and comparable to previous designs of a similar nature. Once the test protocol was finalised, data were collected from three experienced snowboarders performing jumps. The loads applied at the lead foot were found to be of high magnitude. Based on previous cadaver research, these high loads coupled with the kinematic data revealed a potential for ankle injury during snowboard landing events.

KEY WORDS: snowboard, ground reaction forces, field test.

INTRODUCTION: The lower body has been reported to be involved in 33 – 43% of all snowboarding injuries (Bladin et al., 2004; Ganong et al., 1992). Of particular concern is the over-representation of Lateral Process of the Talus (LPT) fractures in snowboarders. Previous epidemiological research found this injury accounted for 34% of all ankle fractures and 15% of ankle injuries (Kirkpatrick et al., 1998). In order to prevent trauma it is important to first understand the underlying mechanisms. Approximately 40% of all snowboarding injuries are sustained while performing aerial maneuvers (Chow et al., 1996). At present the loads applied to the lower body with jump landings have not been quantified. Such an analysis would benefit prevention of lower limb injuries and has been supported within the literature (Funk et al., 2003).

This work was aimed at developing a testing procedure to allow the collection of accurate data in a real snowboarding environment. Specialised portable measuring equipment was designed and validated to allow for this approach to data collection. The finalised procedure and equipment is intended for use in future injury prevention studies.

METHOD:

Data Collection: This work can be divided into three phases outlined below:

Validation of video calibration technique

A system of four high speed cameras (Basler Vision Technologies, Ahrensburg, Germany) running through SIMI motion software was used for on-snow video data collection. A calibration technique was developed to maximise measurement accuracy over an adequate collection volume. This calibration technique utilised a calibration cube and wand (Motion Analysis Corporation, Santa Rosa, USA). To expand the limited volume of the calibration cube, a series of still images were taken with the wand projecting outward from the cube to cover an approximate area of 3 x 1.5 x 1.5 m. The cube and wand images were then overlaid to be used as the calibration object. This part of the study served to quantify the advantages, if any, of this technique over a standard cube calibration. Nine trials were recorded with markers positioned in the periphery of the capture volume. Coordinate data were calculated both ways for each trial and compared to a reference measure, taken from an eight camera motion analysis system. Average and maximum measurement errors were calculated for each coordinate over all trials.

Snowboard force plate accuracy tests

A snowboard mounted force platform (SFP) was designed to fit beneath the bindings of any standard snowboard (see Fig. 1). Six unidirectional force transducers were fixed between two aluminium plates in an arrangement inspired by the Stewart Platform. The complete prototype measured 40 mm thick and had a mass of 2 kg. The accuracy of the SFP was assessed under static and dynamic loading conditions. A Bertec floor-mounted force platform was used as the reference measure for these tests. The plate was tested under static and dynamic conditions with loads up to 1.6 kN. Three trials were recorded for each loading condition. Error calculations were made for all force and moment components. The plate's co-ordinate system was defined in accordance with the right hand rule, with the x, y and z axes in the medial-lateral, anterior-posterior, and vertical measurement directions respectively.

Figure 1 The SFP with bindings mounted on top

Collection of preliminary on-snow data

On-snow kinematic and kinetic data were collected from three experienced snowboarders performing a series of jumps. A four camera SIMI motion system (Unterschleissheim, Germany) was used to collect video data at 120 Hz. A set of 23 black markers were fixed bilaterally onto white tights worn by the participants. The SFP was mounted beneath the lead foot and data were collected by a data logger at 960 Hz. The amplifiers, power pack and data logger were housed within a compact backpack. Only the landing phase of jumping was analysed. Ankle joint kinematic data were calculated based on boot and shank markers. Ankle joint range of motion was calculated for all joint axes. Mean values of each measure were calculated for each participant individually.

RESULTS AND DISCUSSION:

Validation of video calibration technique

Differences were observed between the two calibration techniques. Moving from the standard cube calibration to the proposed wand-cube technique, mean absolute errors decreased from 3.6 mm to 3.1 mm, from 3.3 mm to 2.5 mm, and 4.8 mm to 4.3 mm for the x, z coordinates and resultant position vector respectively. An increase in mean error was seen for y coordinate values. There were no significant differences between the error values calculated for the two calibration techniques; $t(9) = 0.93$, $p = 0.928$. Maximum error decreased when using the wand procedure for all vector components. This was most apparent for the x coordinate where maximum error was reduced by half from 20.5 mm to 10.4 mm. Based on these results it was concluded that the new wand-cube calibration technique affords superior measurement accuracy in the periphery of the capture volume. Therefore this technique should be included in future on-snow testing protocols. This increased accuracy is mainly through a reduction of maximum absolute errors.

Snowboard force plate accuracy tests

The mean absolute error of the calculated vertical static load was 12 N ($SD = 10.2$). The maximum error seen for this incremental loading was 37.3 N. The response to loading was found to be linear with a correlation between the applied and calculated load of $r(15) = 0.9997$, $p < 0.001$. Table 1 summarises the results of the dynamic loading tests. The magnitude of error differed between the measurement axes of the snowboard force plate.

Table 1 RMS error results for all GRF output components of the SFP under dynamic loading conditions

RMS Error (N or Nm)	**Force Component**					
	Fx	**Fy**	**Fz**	**Mx**	**My**	**Mz**
mean	13.4	15.9	59.9	2.2	8.4	6.5
SD	2.3	1.8	23.5	1.1	0.3	0.9
max	15.9	18.3	80.8	3.0	8.8	7.1

Visual inspection of the force traces revealed agreement between the SPF and the standard measure for most GRF components. The Fx, Fy, Fz and Mx components matched very closely in both magnitude and timing. Expressed as a percentage of applied load, the dynamic measurement errors of 5.4%, 5.8% and 2.2% of applied load for the x, y and z force components respectively compare well to previous force transducer design studies, as did errors for the x and y moments. Errors below 5% were found for vertical force and horizontal axis torques in the first of two snowboarding kinetic studies published to-date (Bally & Taverney, 1996). In summary, the dynamic load response of the SFP was satisfactory.

Collection of preliminary on-snow data

GRF and kinematic data are presented for participants one and two only. A similar range of ankle dorsiflexion was observed for both participants following ground contact (subject one *M* = 13°, (*SD* = 2.1), subject two *M* = 15° (*SD* = 8.6)). The snowboarders landed with their front foot in an abducted position. Following touch-down, both underwent further abduction of the ankle joint with subject two exhibiting increased range of motion. Average abduction ROM values were *M* = 6° (*SD* = 2.9) and *M* = 13° (*SD* = 1.4) for subjects one and two respectively. Both participants landed with inverted ankle joints. After ground contact a different pattern of movement was observed for each. Subject one moved to a position of decreased inversion whilst subject two moved through further inversion.

Peak force and moment results are presented in Table 2. Vertical GRF force peaks of 4.79 BW (*SD* = 0.66) and 3.74 BW (*SD* = 0.30) were calculated during the impact phase of landing for participants one and two respectively. Force peaks in the shear directions were of lower magnitude.

Table 2 Mean peak GRF for each participant over all jump landings (N=5). *SD presented in italics*

		Fx		**Fy**		**Fz**	
Peak Value (BW or BW.m)	**Subject 1**	1.45	*(0.41)*	1.77	*(0.49)*	4.79	*(0.66)*
	Subject 2	1.33	*(0.69)*	1.13	*(0.36)*	3.74	*(0.30)*

The direct collection of kinematic and kinetic data distinguishes this research from previous snow sports impact studies (Gerritsen et al., 1996; Grewal, 2002; Hull et al., 1999; Read & Herzog, 1992). As expected, vertical ground reaction forces of high magnitude were recorded during landing, with mean values greater than that found for ski jump landings (Schwameder & Muller, 1995). Boon et al. (2001) found an external axial load range of 2200 to 8900 N was required to produce an LPT fracture in their cadaver specimens. A constant axial load of 2500 N was sufficient to produce an ankle injury in nine out of ten ankle specimens as reported by Funk et al. (2003). Considering this, the vertical external loads of 3521 N (*SD* = 482.2) and 2497 N (*SD* = 220.3) for subjects one and two respectively may be potentially damaging to the ankle under certain joint positions. The average ankle dorsiflexion movement range of 13° to 15° during landing is of lower magnitude than the test positions used in previous cadaver studies; 20° to 30° (Boon et al., 2001; Funk et al., 2003). Participants landed in an inverted ankle position which was maintained throughout the impact phase of landing. Subject one moved to a position of reduced inversion following landing, whereas subject two moved into further ankle inversion. In both cases, the minimum ankle inversion angle did not decrease below 15°. An ankle inversion angle of 10° produced ankle injuries of varying diagnoses for nine out of ten ankle specimens when coupled with forced dorsiflexion and an axial load of 2200 to 8900 N (Boon et al., 2001). Therefore, based on Boon et al. (2001), the position ankle inversion, and magnitude of external load with snowboard jump landings may be of sufficient magnitude to produce ankle injury, especially if the participants were forced into further ankle dorsiflexion.

Based on our reference experiments we conclude/plan that full inverse dynamics analyses are possible. A second platform will be constructed and applied in future studies using this experimental protocol.

CONCLUSION: Methods of kinematic and kinetic data collection for snowboarding were investigated. Through various performance tests these methods were found to be appropriate for on-snow data collection. Pilot testing showed that there is substantial ankle joint loading during jump landing situations. Based on previous cadaver studies, these joint loads may carry the potential for ankle injury. The technique outlined within this paper will allow further understanding of injury mechanisms and the evaluation of interventions. Currently there is no published research of this kind. These data provide a base to be built upon by future biomechanics research.

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