BIOMECHANICAL ANALYSES OF SNOWBOARD JUMP LANDINGS

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Snowboard jump landings represent an important topic of study within the area of sports biomechanics. This is due to the high risk nature of this activity and the potential to modify this risk through equipment design and skill development. This paper presents a summary of a comprehensive series of experiments designed to quantify landing biomechanics and the influence of external factors on the measures taken. Data were collected on-snow from participants performing straight aerials over table top snow jumps. Ground reaction force as well as joint kinematics and kinetics were found to be sensitive to boot wear, binding angle and jump dimension changes. The data collected form a base on which equipment design and injury prevention strategies may be developed.

KEY WORDS: snowboarding, jump landings, ground reaction forces, kinematics.

INTRODUCTION:

The snowboarder represents a new breed of sports person who encounters a unique set of injuries. This statement holds true for rates, severity and location of injury. The unique style of riding and equipment used distinguishes snowboarders from other snow sports participants. Further, the emphasis on jumping has led to a high incidence of falling and impact injuries (Sakamoto & Sakuraba, 2008). Jumping coupled with soft shelled boots, considered optimal for freestyle riding, is believed to account for an increased rate of ankle injuries compared to general snowboarding movements; both fractures and sprains (Kirkpatrick et al, 1998). Jumping will always be popular in snowboarding; it is therefore important to understand the potential mechanisms of injury associated with this skill. From there, potential injury prevention strategies can be developed to decrease risk while facilitating performance.

A recent qualitative observational analysis of landing and falling events within terrain parks revealed that snowboarders fall once for every five attempts (McAlpine & Kersting, 2007). Landing technique was found to influence the risk of falling, and potentially dangerous body motions were identified during controlled landings and falls. These data coupled with epidemiological studies provided motivation for further quantitative studies. The present studies aimed to develop a normative database of landing dynamics and investigate the influence of snowboarding equipment modification on the measures taken. This paper presents a summary of these subsequent studies, each of which linked directly to the overall goal of furthering the limited data available on the biomechanical demands placed on snowboarders during jump landings.

METHODS: Between 2008 and 2009 data collection for a total of four studies was performed at various snow venues. Two studies aimed to investigate the influence of foot rotation angle (neutral vs. external foot rotation); one investigated boot wear (new vs. season old boots); and the final study jump dimensions; on landing mechanics. Custom-built snowboard force plates were used to quantify all components of landing ground reaction forces (GRF) at 1000 Hz. A snowboarding ankle anatomical model was used to estimate joint kinematics, lateral ankle ligament strain, and joint reaction moments based on 3D marker data recorded with a video based system (SIMI motion, 100 Hz). Tests of precision and validity for these unique tools were conducted and presented prior to inclusion into the individual studies (McAlpine, 2010).

Figure 1: The snowboard force plate arrangement as used for on-mountain testing.

Across the four studies a total of 152 on-snow jumps were recorded for 16 individuals. All participants performed straight aerials over a table top snow jump (7.5 to 15 m length). For the boot and binding angle intervention studies, tests for normality indicated the assumptions for parametric tests could not be met; therefore between-condition differences were tested for using Wilcoxon Signed Rank tests with the significance threshold set at $p < 0.05$. Additionally, all data (N=152 landings) were pooled to provide descriptive statistics and normative values of landing parameters. From the larger data set between-limb asymmetries were tested using independent t-tests and a regression analysis was used to identify the effect of jump size on landing GRF.

RESULTS AND DISCUSSION: As expected the external load applied at the boot sole is substantial during the landing event. The population mean of measured peak compression force was 4.14 BW (SD 1.63) and 4.10 BW (SD 1.66) for the front and back foot respectively. The data demonstrated that the magnitude of the linear GRF components for jump landings is greater than that experienced during snowboard carving however the moments were not (Klous, 2007). The clear technique differences between these two snowboarding disciplines accounts for these discrepancies.

During landing the snowboarder is forced into flexion at the ankle and knee. Additionally the fixed non-release bindings and wide stance adopted by snowboarders' creates an initially inverted subtalar joint (both limbs) which persists throughout the landing motion. To control the body kinematics during the landing impact event predominant eversion and plantarflexion muscle moments are present across the subtalar and ankle joints respectively.

Table 1
Mean kinematic and kinetic measures for the ankle joints across all landings (N = 152) (standard deviation bracketted).

	subtalar inversion		**ankle dorsiflexion**	
limb	back	front	back	front
maximum angle (°)	30 *(9)*	31 *(6)*	29 *(5)*	12 *(6)*
reaction moment (Nm/kg)	-0.56 *(0.46)*	-0.77 *(0.36)*	-2.19 *(1.39)*	-1.33 *(1.45)*

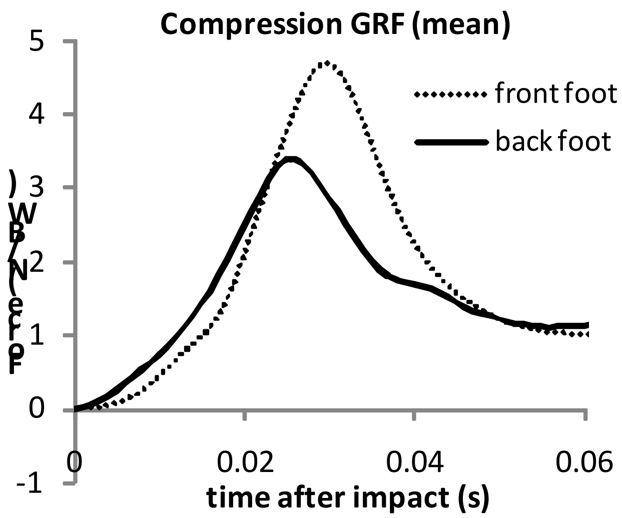

Figure 2: Representative mean compression GRF trace for a single participant.

T-tests identified asymmetries between the limbs for the kinematic and kinetic measures. Typically the rear ankle and knee joints were held in a more flexed position at initial contact, subsequently moving through a greater range of flexion during impact absorption. These data highlight the fact that simplified single limb analyses in snowboarding cannot be generalised to both limbs. Asymmetries also have implications for equipment design, providing potential for foot-specific boot and binding design strategies, such as boot stiffness levels tailored to individual limbs.

Although high, the peak forces and joint angular deflections recorded across the current studies are below published injury threshold data (Funk et al., 2002, Parenteau et al., 1998), suggesting the general risk of injury to the ankle is low during normal controlled jump landings. Nevertheless external factors were identified that carry potential for injury risk modification during landings by eliciting changes in external force, joint kinematics and moments acting at the joint level. Focusing on jump size, all GRF dependent measures except moments about the medio-lateral foot axis (rate and magnitude) and centre of pressure deviation were significantly related to jump size. Although significant, the relationship between jump size and GRF was not entirely strong predicting at best 33% (range 5 – 3%) of the variation within the data. Other factors such as landing strategy, surface variation, snow stiffness, jump trajectory and body position at landing, to name a few, must also be involved. Little attention has been paid within the biomechanics literature to these potential sources of variation, and therefore there is potential for further research on this topic.

The intervention studies identified that both boot stiffness and binding angle adjustments can elicit detectable changes in kinematic and kinetic measures at the boot sole and joints up to at least the knee. The binding alignment studies suggest that aligning the feet more closely with the edge-edge axis of the snowboard compared to a stance of more pronounced external rotation of the feet, caused greater external moments about the long axis of the boot sole with corresponding increases in subtalar inversion motion as well as eversion joint moments to accommodate the external loads.

A significantly greater range of back limb subtalar inversion was detected when comparing new vs one season old boots; mean 14° (SD 7°) vs 18° (SD 6°). These data indicate a protective effect of new boots by limiting the degree of subtalar motion. There may however be a trade-off with the stiffer new boots resulting in a greater rate of GRF application to the snowboarder's foot (non-significant change).

These data form a starting point for further in-depth analyses of snowboard specific movements from perspectives of injury prevention and performance maximisation.

CONCLUSION: The current studies revealed that the external load applied at the boot sole is substantial during the landing event with the joints of the ankle complex rotating to positions close to physical ROM limits. Binding angle and boot stiffness appear to carry potential for injury risk modification during landings by eliciting changes in external force, joint kinematics and moments acting at the joint level. Jump dimensions were found to influence the impact loads applied to the body with both magnitude and rate of measured GRFs found to increase with jumps of greater size. Overall the risk of injury appears to be low within controlled landings, however falling events and undesirable landing positions (on the snow jump) cause a shift from typical landing biomechanics toward a more hazardous situation. Snowboarding is a popular sport in most countries with alpine environments, therefore minimisation of injury risk factors though in-depth biomechanics research will benefit all who participate at a competitive or recreational level.

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