

INFLUENCE OF STANCE POSITION ON STRESS AND PERFORMANCE
FACTORS DURING SNOWBOARDING

by

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ABSTRACT

Little research has been conducted regarding snowboarding; there have been no published studies examining the stress response to snowboarding. Snowboard switch riding is a variation in the performance that is in a body orientation opposite the preferred stance position. **PURPOSE:** To compare general stress response as measured by rating of perceived exertion (RPE), mental stress index, heart rate (HR), and blood lactate (LA), as well as performance factors as measured by degrees of snowboard tilt (tilt), and finishing time (time) in the preferred stance (*PS*) and switch stance (*SS*). **METHODS:** Thirteen snowboarders, ten males and three females (Mean \pm SD; Age: 27 ± 5.39 y) participated in the study. All participants were considered advanced riders based on selected American Association of Snowboard Instructors Riding Standards for level III certification. One subject was unable to complete the protocol. Subjects reported to the Movement Science Lab at MSU Bozeman for height and weight measurements. Subjects then arrived at Bridger Bowl Ski Area, Bozeman MT to snowboard on one visit. Each subject wore a HR monitor chest strap and wristwatch, had a gyroscopically controlled tri-axial accelerometer attached to their snowboard. Subjects rode through a gated course of eleven gates placed with 13-meter vertical and three-meter horizontal displacement once in *PS* and once in *SS*. After completing the course in each condition, RPE, mental stress, physical fatigue, and level of discomfort were assessed; blood lactate was measured three minutes after each trial. HR, tilt, and time data were downloaded and analyzed *a posteriori*. **RESULTS:** Time increased significantly in *SS* ($p = 0.001$). Tilt was significantly lower in *SS* ($p = 0.005$). Rating of perceived exertion was not statistically different, however the effect size was moderate (0.6). HR, and ratings for variables on the mental stress index were not significantly different between conditions. There was no difference in LA. **CONCLUSION:** The current study indicates that *SS* snowboarding increases general stress over *PS* and is associated with lesser skill and decreased performance. Instruction should focus equally on *SS* and *PS* snowboarding. Further studies should alter the turn geometry to mimic free riding, and increase course length.

CHAPTER 1

INTRODUCTION

Snowboarding was created in the US during the 1960's as an alternative to alpine skiing: it has since developed into a competitive and popular winter sport with growing standards of performance. Formal recognition in the Nagano winter Olympics vaulted snowboarding into prominence and it has grown at an exponential rate, nearly equaling skiing in popularity (Canadian Ski Council, 2006; National Sporting Goods Association, 2012; O'Shea, 2004). Increased participation and popularity, however, has not been met with a concomitant increase in basic research regarding the sport. Given the nascence of snowboarding, research has been sparse and focused mainly on injury rate and type, as well as biomechanical analysis of the ankle joint (Delorme, Tacoularis, & Lamontagne, 2005; Estes, Wang, & Hull, 1999; Woolman & Wilson, 2004; Woolman & McNair, 2006).

Novice and elite snowboarders alike can benefit substantially from basic research and improvements in our understanding of the sport. Novice snowboarders are injuring themselves more frequently than skiers, and competitive snowboarders training programs are based mostly from those of alpine ski racers due to a lack of information from which sports scientists and coaches can base their theory and practice (Kim et al, 2012; Turnbull et al, 2011).

Snowboarding differs from alpine skiing in that participants ride with feet attached to a single board, whereas skiers ski with a bilaterally independent stance on two

skis. An individual standing on a single board (e.g., snowboard, skateboard, surfboard) must choose a lead foot and usually face perpendicular to the direction of travel in order to maintain balance. On a snowboard the rider has the option of riding left-foot forward (popularly known as *regular*) or right-foot forward (popularly known as *goofy*). A majority of snowboarders adopt the regular stance due to dominant foot issues (Woolman, 2008), however, foot dominance does not always determine direction of travel. A snowboarder typically uses their rear leg to steer and change direction; therefore, the dominant leg in snowboarding is generally the rear leg. This control requires unilateral limb-specific automaticity in the developing and advanced riders.

Practicing physical tasks with one limb (e.g. unilateral strength training, or unilateral sport-specific movement) has been shown to increase performance capability, strength, and automaticity in the homologous muscles of the contralateral limb (Haaland & Hoff, 2002; Munn et al., 2005; Poldrack et al., 2005). This phenomenon is known as cross-education or bilateral transfer (Magill, 1993). However, the degree of skill transfer from preferred-stance to snowboard switch riding is unknown.

When a rider straps on a snowboard to ride, there are a number of different objectives: free riding, park, or racing. Free riding refers to a normal day of riding in which the purpose is generally recreational. Park riding is more extreme, requires considerable skill and balance, and involves riding rails or boxes, going off man-made jumps and performing tricks such as spins and board-grabs, and riding through a half pipe. Racing involves high speeds on gated courses in which the rider will make tighter

turns than one who is riding recreationally. Due to the dynamic nature of the sport, snowboarders often have to ride switch, the stance opposite their preferred stance (regular or goofy). For instance, when riding the half-pipe event, or big air, snowboarders often land a trick in their switch stance. Additionally, to be formally considered an expert snowboarder, the American Association of Snowboard Instructors (AASI), has defined riding performance standards that must be met which include sufficient skill in the switch stance. For example, level three certification requires snowboarders to skid short and medium radius turns on black terrain in their switch stance, carve large radius turns on green trails, and perform freestyle features including 180° mid-air rotation off small man-made features-thereby landing in the switch stance. Therefore, a snowboarder must master locomotion in two domains, preferred and switch.

Switch riding is often an uncomfortable position that may increase a rider's stress response and alter performance. The human response to stress is complex and is the sum of changes that occur resulting from numerous non-specific factors (Selye, 1985). Heart rate is a sensitive physiological marker that is easily measured (Vrijkotte, van Doornen, & de Geus, 2000) and can offer insight into the stress response of snowboard switch riding. Rating of perceived exertion (RPE) can also offer a simple subjective measure of the whole-body stress response (Noble & Robertson, 1996). Furthermore, blood lactate is a commonly measured physiological variable used to provide insight into the intensity of a physical activity (Wilmore & Costill, 2005). Therefore, the purpose of this investigation was to better understand the stress and performance factors associated with snowboard

switch riding to determine whether physiological variables and RPE differ between preferred and switch-stance snowboarding techniques.

Statement of Purpose

The purpose of this study was to analyze physiological stress as measured by heart rate (HR), blood lactate (La), whole-body RPE, mental stress, level of discomfort, and physical fatigue, as well as performance factors including maximum degrees of snowboard tilt through the turns, and time to completion through a gated course with standardized turns. This research is important because of a lack of basic knowledge about the sport, the frequency of injuries incurred by snowboarders, and to provide information about the development of snowboarding skill.

Hypothesis

The null hypothesis was that there will be no difference in mean values for peak heart rate (HR) rating of perceived exertion (RPE), blood lactate (LA), mental stress (MS), level of discomfort (LOD), physical fatigue (PF), time to completion (T), or snowboard tilt (Ti) between preferred stance (PS) or switch stance (SS) snowboarding. The alternative hypothesis was that there would be a difference in mean values for variables during snowboarding in each stance position.

$$H_0 : \mu(\text{PS}) = \mu(\text{SS})$$

$$H_A : \mu(\text{SS}) \neq \mu(\text{PS})$$

Delimitations

The study was delimited to male and female snowboarders of advanced ability. Subjects were required to provide their own snowboard and boots. Data collection was performed during the winter of 2012-2013, and the slope was groomed the night prior to data collection given new snow. Additionally, the course was slipped prior to all trials given new snow had fallen between trials, or the course became uneven due to use. Each subject performed two trial runs—one *PS* and one *SS*

Assumptions

It was assumed that snow and weather conditions would not change significantly between trials and that all subjects would perform to the best of their ability throughout the experiment.

Limitations

The sample size of this study was small ($n = 12$) therefore generalizations to the larger population of snowboarders were made with caution. Additionally, snow conditions cannot be controlled, and snow stiffness may affect muscular work and therefore potentially stress. Although subjects were chosen for inclusion in the present study based on their ability to perform selected AASI riding standards for level III certification, the investigator was not formally trained in assessing these performance standards.

Definitions

Edge Change refers to moving from the toe-side to heel-side edge or vice versa.

A *turn* refers to an edge change during snowboard riding (Schwameder, Nigg, Tschärner, & Stefanyshyn, 2001) that is associated with a change of direction.

Preferred refers to the rider's preferred stance on a snowboard that is most comfortable.

Switch refers to the rider's stance opposite that which is preferred.

Goofy refers to the preferred stance in which the snowboarder rides right-foot-forward.

Regular refers to the preferred stance in which the snowboarder rides left-foot-forward.

Tilt refers to the degrees of deflection of the snowboard along the perpendicular axis with respect to the hill surface.

A *Trial* refers to one data-collection run from the start to finish of the pre-determined course.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Snowboarding began in the 1960's as a low-tech activity in which people rode a board with an attached handle, no foot straps, and little control; it has since evolved into a high-speed, highly skilled competitive snow sport that gained formal recognition in the Nagano winter Olympics in 1998 (Canadian Ski Council, 2006; O'Shea, 2004). In the early 1980's, snowboarding was banned from many ski areas due to liability issues and a lack of knowledge about the sport (Pino & Colville, 1998). Snowboarding has since come a long way: in 2010 the National Sporting Goods Association (NSGA) observed that there were 7.4 million alpine skiers and 6.1 million snowboarders in the US alone (NSGA, 2012). Increased participation brought about an increase in injuries. According to Kim et al (2012), snowboarders experience more injuries than alpine skiers: the mean days between injury over 18 seasons at a Vermont ski area were 345 for snowboarders compared to 400 for skiers. In addition, snowboarders experience 2.4 times as many fractures, far more ankle injuries, although fewer knee injuries compared to skiers (Bladin & McCrory, 1995). Most snowboard studies have highlighted the mechanisms, rates, and types of injury (Davidson & Lalotis, 1996; Dohjima, Sumi, Ohno, Suni, & Shimizu, 2001; Fong, Hong, Chad, Yung & Chan, 2007; Funk, Srinivasan & Crandall, 2003). Most snowboarding injuries occur in novices who have received little instruction (Dohjima et al., 2001; Bladin et al., 1991), therefore quality instruction may help attenuate some of the injury risk to novice snowboarders. While previous research has

focused on injury, little is known of the human stress-related response to snowboarding. Furthermore, to date, no research has been done analyzing the HR, RPE, board tilt, or lactate response when snowboarders ride in their switch stance.

Alpine skiing has been the focus of numerous experiments regarding the mechanics, physics, and physiological factors that occur during skiing including hydration, muscle damage, and muscle recruitment (Karlsson, 2005; Lind & Sanders, 1996; Nordt et al., 1999a; Nordt et al., 1999b; Seifert et al., 2005). Snowboard-specific research has focused primarily on mechanisms of injury (Bladin, Giddings, & Robinson, 1993; Dohjima et al., 2001), and mechanics during jump landings (McAlpine & Kersting, 2006; O'Shea, 2004). The current deficiency of basic research underlies the need for continuing investigation into this popular sport.

Given the greater prevalence of ankle injuries in snowboarders than skiers, snowboarding research has also focused on ankle-joint properties in the field (Delorme et al., 2005; Woolman & Wilson, 2004; Woolman & McNair, 2006) and in a laboratory setting (Estes et al., 1999). In Bally and Taverney's study (as cited in Johnson and Schaff, 1996), ground reaction forces and inversion-eversion forces transmitted by the feet on a snowboard during linked turns were investigated. Ground reaction forces were measured using a force transducer with values of up to 1540 and 1740 Newtons, and up to 1070 and 780 Newtons for inversion-eversion forces for the rear and front foot respectively. No correlation was found between rider weight and forces measured. In the same way, Knunz, Nachbauer, Schindelwig, & Brunner (2001) reported that peak ground reaction

forces were consistently greater for the rear leg when measuring heel and toe-side turns on a snowboard, emphasizing that the rear leg is more active during direction change and steering than the front leg. Additionally, Klous, Müller, & Schwameder (2007) reported that ankle joint moments are larger in snowboarders than skiers, with the highest values occurring in the rear leg. Similarly, Delorme et al (2005) found that ankle dorsiflexion was consistently greater in the rear foot, and Woolman (2008), reported that rear foot musculature is more active during snowboarding turns. These data support the notion of laterality in snowboarding: snowboarding in either direction is a unilaterally dominant motor pattern where one limb produces a majority of the control.

Lower-limb injury patterns seem to be indicative of the forces experienced by participants: increased forces in the knee of skiers are accompanied by greater knee injury levels; greater ankle-joint forces in snowboarders come with increased ankle injury rates (Klous, Müller, & Schwameder, 2007). This injury pattern may be partly explained by boot type: snowboarders wear soft boots that allow for more ankle motion than ski boots, whereas stiff ski boots limit ankle motion, transferring forces to the knee.

Laboratory investigation may be insufficient for studying a dynamic activity such as snowboarding due to the large distances covered during participation and the severe conditions such as uneven terrain, presence of obstacles, and environmental conditions (Klous, Müller, & Schwameder, 2007; Kruger & Edelmann-Nusser, 2009). A groomed ski slope can maximize safety of subject participation as well as consistency of results because the snow is compacted and the conditions are as standardized as possible (Kruger

& Edelman-Nusser, 2009). Additionally, the firmness of the snow may affect muscle activity (O'Shea, 2004) and therefore stress factors. Stress associated with snow conditions may influence the performance of the rider, as well as the type of turn made during free riding.

There are two types of turns in snowboarding: a skidding turn and a carving turn (Klous et al., 2007). A skidding turn is that which involves sliding across the snow when the snowboarder leans in order to use the uphill edge (heel-side or toe-side) of the snowboard against the snow in a braking fashion with more vertical than horizontal displacement. During a carving turn the snowboard edge cuts into the snow creating a more symmetrical turn. Carving turns require more hip muscle activity, greater skill, and will involve greater stress on the body in general over skidding turns (Hamill & Knutzen, 1995; Klous et al., 2007). The muscles that extend the hips, including the gluteus maximus and hamstring muscles, are most active during carving turns (Woolman, 2008). These muscles produce the most force in the body, thereby creating the greatest acceleration in hip-dominant movements such as snowboarding turns (Hamill & Knutzen, 1995; Johnson, 1991).

Snowboarders must choose a lead foot when riding as the sport requires orientation perpendicular to the direction of travel; the rear leg is that which produces most of the control during turns. Woolman (2008) suggested that a majority of snowboarders chose the left-foot-forward stance due to limb dominance; however lower limb dominance (i.e. lateral dominance) is not well defined (Miyaguchi & Demura, 2010). The lower limb

does not seem to present lateral dominance in the same manner as the upper limb: individuals tend to choose the left leg for strength and balance activities, whereas the right leg is more often chosen for fine motor control (Miyaguchi & Demura, 2010; Wagner, 2010). According to Wagner (2010), the brain's left hemisphere, which provides control of the right side of the body, is more dominant and provides better neuromuscular control during movement, offering an explanation for regular stance orientation in a majority of snowboarders. It appears, then, that there is no 'dominant leg' *per se*; the leg chosen for a specific motor pattern is based on subjective decision of the individual and preferred patterns specific to the movement (Wagner, 2010).

In addition to the biomechanical stressors placed on the body during snowboarding, physiological stress is also inherent to performing a downhill snow sport and can be quantified using common techniques, for instance, heart rate. Heart rate (HR) monitors are commonly used to track the intensity of a physical activity, as HR varies based on the physical stress imposed on the body (Zatsiorsky & Kramer, 2006), and can be affected by the psychological stress and increased catecholamine response (Dishman, Nakamura, Garcia, Thompson, Dunn, & Blair, 2000; Noble & Robertson, 1996). Elevated psychological stress is inevitable when performing an activity in an abnormal fashion (Noble & Robertson, 1996), such as during snowboard switch riding.

Stress does not have a single root cause; as it pertains to human activity stress is an umbrella term for changes that occur within the body due to non-specific causes (Selye, 1985). Bernard and Krupat (1994) developed the Biopsychosocial Model of

Stress, indicating that stress consists of an external component, an internal component, and an interaction between the two. The external component involves environmental stressors that can elicit the general stress response (e.g., a gated mountain run with standardized turns), while the internal component involves biological changes (e.g., mental stress), which, in combination, can cause an interaction resulting in a greater stress response (e.g., increased HR). Stress causes an increased sympathetic response, which in turn increases HR. One common method for measuring the general stress response is RPE.

The Borg Scale for RPE is a subjective scale used to assess the stress response and work intensity of an individual (Noble & Robertson, 1996). The scale numbers have words associated with them in order to help standardize scores (Borg, 1998). The category-ratio (CR10) scale has values that range from 0 to 10 with more values at the end of the scale, unlike the original Borg RPE scale with values from 6-20 because perceived stress increases disproportionately at higher levels of intensity (Noble & Robertson, 1996). Problems with the original scale were found due to the 1.6 exponent of Stevens' Law: as the workload approaches higher levels, an individual's perceived exertion increases disproportionately when compared to lighter workloads (Teghtsoonian, 1971). Therefore, the CR10 scale was utilized in the present study to measure whole-body perceived exertion. In addition to whole-body exertion, the specific effect of snowboarding on psychological stress was assessed. The mental stress index utilized in the present study was adapted from a mental fatigue index used by Ohru and colleagues (2008). This index is a simple questionnaire that addresses three items (mental stress,

level of discomfort, and physical fatigue) on a 3-point scale (0=none, 1=small, 2=high). In addition to RPE, stress associated with high intensity activity may be manifested in an accumulation of lactate in the blood.

Lactate accumulates in the blood during short-duration, high-intensity activities, such as snowboarding through gated turns, due to a lack of balance between production and removal (Wilmore & Costill, 2005). The concentration of blood lactate does not peak immediately following physical activity due to the amount of time necessary to buffer and transport lactate from the cell to the blood stream (Juel, 1988). According to Stone et al. (1987) lactate levels were lower in trained individuals than those with less training experience at any given workload during weight training (except at the point of exhaustion). This seems to suggest that trained individuals have a higher tolerance for the accumulation of lactate in the blood. In the present study, physical fitness was not a factor considered; however, it was assumed that expert snowboarders could be considered “trained” in that snowboarding is a learned physical skill with similar specificity of neuromuscular adaptation.

Given the deficiency in basic research into the stress and performance characteristics of snowboarding the present study was conducted to analyze and measure the general stress response to snowboard switch riding, as well as basic performance factors when advanced-level snowboarders ride switch.

CHAPTER 3

INFLUENCE OF STANCE POSITION ON STRESS AND PERFORMANCE
FACTORS DURING SNOWBOARDING

Contribution of Authors and Co-Authors

Manuscript in Chapter 3

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Contributions: Aided in study design, executed data collection, processed and analyzed data, and wrote manuscript.

Co-Author: Dr. John G. Seifert

Contributions: Discussed study design, results and interpretations, and reviewed final manuscript.

Co-Author: Dr. Mary P. Miles

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Contributions: Discussed study design, results and interpretations, and reviewed final manuscript.

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Abstract

Little research has been conducted regarding snowboarding; there have been no published studies examining the stress response to snowboarding. Snowboard switch riding is a variation in the performance that is in a body orientation opposite the preferred stance position. **PURPOSE:** To compare general stress response as measured by rating of perceived exertion (RPE), mental stress index, heart rate (HR), and blood lactate (LA), as well as performance factors as measured by degrees of snowboard tilt (tilt), and finishing time (time) in the preferred stance (*PS*) and switch stance (*SS*). **METHODS:** Thirteen snowboarders, ten males and three females (Mean \pm SD; Age: 27 ± 5.39 y) participated in the study. All participants were considered advanced riders based on selected American Association of Snowboard Instructors Riding Standards for level III certification. One subject was unable to complete the protocol. Subjects reported to the Movement Science Lab at MSU Bozeman for height and weight measurements. Subjects then arrived at Bridger Bowl Ski Area, Bozeman MT to snowboard on one visit. Each subject wore a HR monitor chest strap and wristwatch, had a gyroscopically controlled tri-axial accelerometer attached to their snowboard. Subjects rode through a gated course of eleven gates placed with 13-meter vertical and three-meter horizontal displacement once in *PS* and once in *SS*. After completing the course in each condition, RPE, mental stress, physical fatigue, and level of discomfort were assessed; blood lactate was measured three minutes after each trial. HR, tilt, and time data were downloaded and analyzed *a posteriori*. **RESULTS:** Time increased significantly in *SS* ($p = 0.001$). Tilt was significantly lower in *SS* ($p = 0.005$). Rating of perceived exertion was not statistically different, however the effect size was moderate (0.6). HR, and ratings for variables on the mental stress index were not significantly different between conditions. There was no difference in LA. **CONCLUSION:** The current study indicates that *SS* snowboarding increases general stress over *PS* and is associated with lesser skill and decreased performance. Instruction should focus equally on *SS* and *PS* snowboarding. Further studies should alter the turn geometry to mimic free riding, and increase course length.

Introduction

Snowboarding was created in the US during the 1960's as an alternative to alpine skiing: it has since developed into a competitive and popular winter sport with growing standards of performance. Formal recognition in the Nagano winter Olympics vaulted snowboarding into prominence and it has grown at an exponential rate, nearly equaling skiing in popularity (Canadian Ski Council, 2006; NSGA, 2012; O'Shea, 2004).

Increased participation and popularity, however, has not been met with a concomitant increase in basic research regarding the sport. Given the nascence of snowboarding, research has been sparse and focused mainly on injury rate and type, as well as biomechanical analysis of the ankle joint (Delorme, Tacoularis, & Lamontagne, 2005; Estes, Wang, & Hull, 1999; Woolman & Wilson, 2004; Woolman & McNair, 2006).

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Snowboarding differs from alpine skiing in that participants ride with feet attached to a single board, whereas skiers ski with a bilaterally independent stance on two skis. An individual standing on a single board (e.g., snowboard, skateboard, surfboard) must choose a lead foot and usually face perpendicular to the direction of travel in order to maintain balance. On a snowboard the rider has the option of riding left-foot forward (popularly known as *regular*) or right-foot forward (popularly known as *goofy*). A majority of snowboarders adopt the regular stance due to dominant foot issues (Woolman, 2008), however, foot dominance does not always determine direction of travel. A snowboarder typically uses their rear leg to steer and change direction; therefore, the dominant leg in snowboarding is generally the rear leg. This control requires unilateral limb-specific automaticity in the developing and advanced riders.

Practicing physical tasks with one limb (e.g. unilateral strength training, or unilateral sport-specific movement) has been shown to increase performance capability, strength, and automaticity in the homologous muscles of the contralateral limb (Haaland & Hoff, 2002; Munn et al., 2005; Poldrack et al., 2005). This phenomenon is known as cross-education or bilateral transfer (Magill, 1993). However, the degree of skill transfer from preferred-stance to snowboard switch riding is unknown.

When a rider straps on a snowboard to ride, there are a number of different objectives: free riding, park, or racing. Free riding refers to a normal day of riding in which the purpose is generally recreational. Park riding is more extreme, requires considerable skill and balance, and involves riding rails or boxes, going off man-made jumps and performing tricks such as spins and board-grabs, and riding through a half pipe. Racing involves high speeds on gated courses in which the rider will make tighter turns than one who is riding recreationally. Due to the dynamic nature of the sport, snowboarders often have to ride switch, the stance opposite their preferred stance (regular or goofy). For instance, when riding the half-pipe event, or big air, snowboarders often land a trick in their switch stance. Additionally, to be formally considered an expert snowboarder, the American Association of Snowboard Instructors (AASI), has defined riding performance standards that must be met which include sufficient skill in the switch stance. For example, level three certification requires snowboarders to skid short and medium radius turns on black terrain in their switch stance, carve large radius turns on green trails, and perform freestyle features including 180° mid-air rotation off small man-

made features-therby landing in the switch stance. Therefore, a snowboarder must master locomotion in two domains, preferred and switch.

Switch riding is often an uncomfortable position that may increase a rider's stress response and alter performance. The human response to stress is complex and is the sum of changes that occur resulting from numerous non-specific factors (Selye, 1985). Heart rate is a sensitive physiological marker that is easily measured (Vrijkotte, van Doornen, & de Geus, 2000) and can offer insight into the stress response of snowboard switch riding. Rating of perceived exertion (RPE) can also offer a simple subjective measure of the whole-body stress response (Noble & Robertson, 1996). Furthermore, blood lactate is a commonly measured physiological variable used to provide insight into the intensity of a physical activity (Wilmore & Costill, 2005). Therefore, the purpose of this investigation was to better understand the stress and performance factors associated with snowboard switch riding to determine whether physiological variables and RPE differ between preferred and switch-stance snowboarding techniques.

The present study was conducted to analyze physiological stress as measured by heart rate (HR) and blood lactate (La), psychological stress as measured by whole-body RPE and mental stress measured with a modified stress index, as well as performance factors including maximum degrees of snowboard tilt through the turns, and time to completion through a gated course with standardized turns. This research is important because of a lack of basic knowledge about the sport, the frequency of injuries incurred by snowboarders, and to provide information about the development of snowboarding skill.

Methodology

Subjects

Thirteen snowboarders (10 males, 3 females) volunteered for this study and were classified as advanced level riders by specifically selected components of the American Association of Snowboard Instructors (AASI) level III certification standards (Appendix C). One subject could not complete the protocol due to technical difficulties. The investigator prior to data collection verified participants' self-reported ability during free riding.

Experimental Design

The Institutional Review Board at Montana State University-Bozeman approved the procedures for this study. All participants provided written consent prior to participation, after being made aware of the potential risks. Each subject participated in two experimental trials during one visit to Bridger Bowl Ski Area in which they rode through the predetermined course once in their preferred stance and once in their switch stance. Order of riding conditions was randomized and counter balanced. Subjects were instructed to move with as much control and consistency through the course as possible in each stance position.

Procedures

Initial testing was performed at Bridger Bowl Ski Area preceding data collection to determine turn geometry for the experiment: a 13-meter vertical and 3-meter horizontal

displacement was marked with colored brush gates. Distances for each turn were measured with verification from a Nikon range-finding device (Nikon, Tokyo Japan).

Subjects were asked to showcase their snowboarding ability in the preferred and switch stance at Bridger Bowl prior to testing in order to verify their self reported ability. Performance criteria for participation are based on selected standards from the American Association of Snowboarding Instructors Riding Standards for Level III National Certification (Appendix C): subjects were required to successfully perform dynamic carved medium radius turns on blue terrain in both stance positions. The investigator verified the ability level of each subject based on these standards prior to their first test run.

Subjects reported to the Movement Science Lab at Montana State University prior to participation for height and weight measurements; in addition, age and years of snowboarding experience were reported (Table 1.). Due to limited hill space, eleven brush gates were used to mark the course. The first two turns were eliminated from data analysis in order for riders to get to a consistent speed, and the final gate was removed from analysis due to a lack of a full turn around the final gate: therefore, 8 turns were analyzed. Data collection took place from January 21st through February 18th 2013 on the *Boot Hill* run at Bridger Bowl Ski Area in Bozeman Montana.

Subjects wore a Polar heart rate monitor chest-strap across the xiphoid process of the sternum along with wristwatch (Polar, Finland). A Shadowbox (Salt Lake City, USA) tri-axial, gyroscopically controlled, accelerometer was attached to the snowboard between front and rear foot with a two-way adhesive and connected to the snowboard

binding with the unit's clip. The Shadowbox was calibrated on a non-metallic surface each day prior to data collection and set to record data points at 50 hertz. The Shadowbox unit was used to measure maximum degrees of tilt (rotation) around the x axis for each turn, as well as time to completion through the course.

After the subject was outfitted with HR monitor and Shadowbox attached to the board, a practice trial was performed in the switch stance for course-orientation. The first data collection trial was randomly selected in either preferred or switch stances. The second trial was that which was not performed first. The investigator instructed the subject to ride with carved turns as controlled and consistently as possible through the course turns (i.e. avoiding large changes in speed and hard slides). The investigator then started the Shadowbox and HR monitor after which the subject performed a jump-start, waited three seconds and began riding through the course. At the end of the course the subject performed another jump to indicate the trial was finished. At this time the investigator stopped the Shadowbox and HR monitor, and began a stopwatch to measure three minutes, after which, blood lactate was taken (Wilmore & Costill, 2005) from a finger-stick sample using a LactatePro system (Arkray KDAK, Japan). During this three-minute period the subject was given a Borg CR10-RPE scale (Appendix A) and asked to provide a subjective measure of their whole-body exertion. In addition, a modified mental stress index (Appendix B) was provided: level of discomfort (LOD), mental stress (MS), and physical fatigue (PF) were rated on a scale of 0-2. In the event that a subject fell during a trial run, the trial was restarted.

Data Reduction

Heart rate data was downloaded using PolarTrainer 5® software: peak HR was recorded for each trial. Data from the Shadowbox was downloaded to Ride Tracker ® software from which tilt and time were recorded. The peak tilt angle at each individual turn was recorded and the mean of all turns per trial are presented. Maximum degrees of tilt that occurred during heel-side and toe-side turns in both domains were also recorded. Finally, time to completion from the edge change between the second and third gate to the edge change preceding the final gate was recorded.

Statistical Analysis

Data are expressed as mean \pm standard deviation and statistical analysis was carried out using SPSS statistical software version 18.0 (SPSS, Inc. Chicago, USA). Percentage change from the preferred stance values is also reported due to subjects testing on different days, and therefore different snow and course conditions. Values for LA, HR, mean tilt, and finishing time measured during preferred-stance trials were compared to those from switch-stance trials using paired t tests. Additionally, heel and toe-side turns were compared with paired t tests. A Bonferroni correction was used in order to reduce the risk of a type 1 error associated with performing multiple t-tests. Significance was achieved when $p \leq 0.01$. Mann-Whitney U non-parametric analyses were performed on RPE, MS, PF, and LOD to differentiate means. Significance was achieved when $p \leq 0.01$. Additionally, Pearson product-moment correlation analyses were performed with finishing time-tilt, finishing time-RPE, and tilt-RPE.

Results

Descriptive data of the participating subjects are presented in Table 3.1. Subjects were 10 males and three females ($27 \pm 5.39y$) with considerable difference in experience ($11.92 \pm 6.86y$). No data was collected from subject #13 due to technical difficulties: analysis was performed on data from 12 subjects (10 males, 2 females). The first week of testing was undertaken during overcast, warm conditions on a slightly icy slope. The final 3 weeks were warm and sunny on most days. No snow fell during the first weeks of testing, or during testing on any given day, however a large snowfall of 10 inches occurred during the final week of testing. Most subjects rode the course with fresh snow that was groomed the night prior to testing, or that was slid prior to testing trials by skis.

Time to completion in switch stance (*SS*) trials ($18.56s \pm 3.9s$) was significantly greater ($p = 0.001$) than preferred stance (*PS*) trials ($15.95s \pm 2.7s$) by an average of 2.61 seconds. The average of peak tilt angles for each turn was significantly greater ($p = 0.005$), in the *PS* ($43.66^\circ \pm 4.39^\circ$) than *SS* ($39.57^\circ \pm 6.73^\circ$) by an average of 4.06 degrees. Rating of perceived exertion was not statistically different ($p = 0.12$) between *SS* (3.08 ± 2.01) and *PS* (2.44 ± 1.03), however, a moderate effect size of 0.6 was calculated using the Cohen's *d* test. Mental stress rating showed a trend toward higher levels ($p = 0.08$) in *SS* (0.92 ± 0.79) compared to *PS* (0.42 ± 0.67), but were not significant. The average peak HR in *SS* ($160.09 \pm 14.90bpm$) was greater ($p = 0.048$) than average peak HR for *PS* ($152.82 \pm 14.97bpm$), but the difference was not significant; however, an effect size of 0.4 was calculated using Cohen's *d*, indicating a moderate effect. Similarly, LOD rating in *SS* (0.67 ± 0.89) was greater on average than *PS* (0.17 ± 0.39) by .5 points, however

there was no statistical difference ($p = 0.67$). There was no difference in PF ($p = 0.31$) or LA ($p = 0.33$) levels between trials. All raw data are reported in tables 2, 3, and 4.

In order to provide a more descriptive picture of the changes that occur in the switch stance, data are expressed as a percentage change from *PS* (i.e., preferred stance = 100%). For instance, time to completion and mean peak tilt angles were significantly different between trials: time increased by an average of 16.23% during *SS* trials and mean peak tilt angles during *SS* were 6.84% lower ($p = 0.001$ and 0.008 respectively). Additionally, HR ($n = 11$) was elevated during *SS* trials by an average of 5.14%, however the difference was not significant.

Means for maximum degrees of tilt during heel-side turns were compared to toe-side turns in both domains. There was no significance between heel and toe-side turns in the switch stance ($p = 0.44$). Heel-side turns showed a trend to greater levels over toe-side turns in the preferred stance, but the difference was not significant ($p = 0.02$).

There was a significant inverse correlation between time to completion and mean peak tilt angles in *SS* and *PS* trials ($r = -0.91$ and -0.71 respectively, $p < 0.001$). Similarly, mean peak tilt angles correlated well with RPE for *SS* and *PS* trials ($r = -0.58$ and -0.66 respectively, $p < 0.001$). There was a strong correlation between finishing time and RPE in the *SS* ($r = 0.55$, $p < 0.001$) but only a weak association was found in *PS* ($r = 0.23$ $p < 0.001$).

Years of experience did not influence performance in the switch stance. There was no difference between board tilt in *PS* ($p = 0.45$) or *SS* ($p = 0.25$) between riders with 11 or more years experience ($n = 6$) compared to those with 10 or fewer years experience

($n = 6$). Furthermore, there was no difference between finishing time in *PS* ($p = 0.39$) or *SS* ($p = 0.27$) for years of riding experience. In *PS* trials there was no difference in RPE ($p = 0.14$), however, there was a significant reduction in RPE when riders had 11 or more years of snowboarding experience ($p = 0.005$).

Discussion

The present study was the first undertaken to measure physiological and psychological stress as well as performance factors associated with snowboard switch riding. Switch stance riding is a type of intervention-induced variation proposed by Ranganathan & Newell (2013) to *PS* snowboarding with the same end goal in order to elicit a stress response, and alterations in performance. The results of this experiment demonstrate that, even with advanced level riders, snowboard switch riding is an unnatural motor pattern associated with increased time taken to ride through a predetermined course, decreased snowboard tilt angles around gated turns, and increased stress as indicated by RPE. Of all twelve advanced-level riders, ten rode in the “regular” stance and two riders rode in the “goofy” stance. Though the sample was not truly random, this provides support for the notion that a majority of snowboarders preferred stance is left-foot-forward.

Time to completion was significantly greater during *SS* compared to *PS* trials and was consistent with expectations. Each condition involved the same task goal: get to the end of the course as quickly as possible while maintaining control. Subjects were instructed to travel as controlled and consistently as possible through all turns, though

riders in the *SS* position still required significantly more time to move through the course. Subjects met selected AASI riding standards for level III certification prior to testing. However, skill was verified during free riding rather than on the test course. Subjectively, the skill level of participants was high in both *PS* and *SS*, however, it took an average of 2.61 seconds longer to complete the task in the switch stance.

Maximum degrees of board tilt were recorded at each turn and were significantly lower in the *SS* trial. Snowboard tilt angles are generally lower in skidding turns than during carving turns as skidding turns are associated with less skill and physical control (AASI, 2012; Klous et al., 2007). During the *PS* trial increased board tilt with respect to the slope forces the rider's center of gravity into greater lean angles (i.e. inclination). When the rider is in control of his or her board within a turn, this inclination is met with altered joint angles at the hip, knee, and ankle (i.e. angulation) which allows the rider to maintain balance and press into the snowboard edge, creating a carved turn (Bogardus, 2013; Michaud & Duncumb, 2013). Significantly greater board tilt in the *PS* trial indicates that the participants were able to carve more effectively, while they skidded more around gates in the *SS*. When heel and toe-side turns were compared, there was no significant difference found between heel side turns or toe side turns in either domain. However, comparing heel and toe-side turns in the preferred stance alone, the difference approaches significance, which seems to indicate that participants in general had more control when riding on the heel-side edge. This may have implications for instruction: increased control on the toe-side edge may require additional practice and instruction in order to improve the overall skill level of the rider.

Although EMG was not measured in the present study, it appeared that a majority of riders were more tense during *SS* than *PS* indicating increased co-contraction and isometric muscle action throughout the body. This notion is supported by the fact that there were no significant differences in HR and LA levels between domains, although finishing time was significantly faster in *PS* than *SS*. Additionally, riders in their *SS* may have had less proportional angulation—disproportionate bending at the waist to knees and ankles (Bogardus, 2013). This forward, or backward, lean appears to be consistent with a lack of, or lesser, control of the snowboard. Bogardus (2013) termed this hip-lean “breaking at the waist,” which involves shifting the center of mass away from the board edge, causing slippage or skidding. Skidding was very clearly more prevalent when riders performed in their switch stance.

Rating of perceived exertion was approximately double following *SS* trials than *PS* trials. Borg scale RPE values were reported greater in the *SS* for 11 advanced subjects, while one subject gave the same rating for each (0.5, extremely weak). Whereas statistical significance was not achieved, a moderate effect was observed between trials ($ES = 0.6$). There appears to be a practical difference in the RPE response to snowboard switch riding. These results indicate that participants generally had to work harder to complete the task and were, therefore, more uncomfortable in the *SS*. Rating of perceived exertion is subjective in nature, but offers quality insight into the comfort level following snowboarding turns. Even though all subjects met the aforementioned riding standards, switch riding is still less comfortable, and therefore more psychologically stressful than the preferred movement pattern.

A strong inverse correlation between finishing time and board tilt was observed in the switch stance: as board tilt decreases, finishing time increases. This illustrates a clear picture: switch riding involves decreased board tilt that is synonymous with skidding, leading to an increased braking component that reduced speed and increased finishing time (reduced skill). An inverse correlation of lesser magnitude, while still very strong, was also found between finishing time and board tilt in *PS*. This provides additional evidence that seems to indicate that increased board tilt is associated with carving turns that may reduce finishing time and is synonymous with greater skill. Additionally, board tilt and RPE are strongly inversely correlated: as board tilt angles decrease, as a result of skidding turns, RPE increases. Though the course was short (eight turns), it is likely that a course of greater length would result in further increases in finishing time and RPE in the switch stance. The association between time and RPE largely disappears in the *PS*.

Peak HR ($n = 11$) was greater, on average, following the *SS* trial compared to *PS* trial by 7.3 bpm, or greater by 5.14%. There was considerable variability in HR data in both conditions, therefore an effect size was calculated using Cohen's d : a moderate effect was found, indicating that there may be a practical increase in HR following *SS* over *PS*. Although the difference in HR was not statistically significant, there were some interesting trends. Three riders had higher peak HR in the *PS*; two of the three were within 3 bpm, whereas subject #5 experienced a 15 bpm greater HR during the *PS*. Subject 5 completed the course two seconds faster with five degrees greater board tilt in the *PS* trial; additionally, this subject reported a higher level of mental stress in the *PS* trial. These results indicate that this subject likely required more muscle activation to

carve quickly around the gates in the preferred stance thereby elevating HR and perceived mental stress; significantly more relaxed during switch riding which can be associated with less isometric muscle activity in contrast to other subjects. Another interesting observation is that peak HR from two of the subjects were 23 bpm and 28 bpm lower than the average during SS. Both of these subjects reported higher RPE, mental stress, and level of discomfort ratings. Physical fitness as measured by respiratory capacity or maximum HR was not assessed in the present study, however it appears that these three subjects may have better cardio-respiratory fitness than the others: lower HR may have skewed the HR results.

Mental stress, one component of the modified stress index, was not significantly different between trials, however trended toward higher values in the *SS*. In the same way, level of discomfort ratings were not significantly different between trials with most participants reporting “0: none,” however subject 4 reported a higher level of discomfort during the *PS* trial. Interestingly, subject 4 also performed the fastest *PS* trial by 1.36 seconds, more than one standard deviation below the mean finishing time, and had a mean board tilt angle one standard deviation above mean values; therefore, the level of discomfort was associated with increased effort due to faster riding, and greater body-lean associated with greater muscle recruitment requirement.

Values reported for physical fatigue were not different between trials. One possible explanation for this is that the course was short; therefore the stimulus was likely inadequate to illicit a physically fatiguing response. This measurement may be more appropriate for longer trials.

Blood lactate was not different between conditions: whereas there is no statistical difference between trials, this tells an interesting story. The similarity in blood lactate levels between conditions in the present study may be attributed to different mechanisms: increased concentric and eccentric muscle action for carving turns in the preferred stance, and therefore increased metabolic cost of movement (Ryschon, Fowler, Wysong, Anthony, & Balaban, 1997); and increased isometric stabilization during skidding turns in the *SS*. When the sample is observed as a homogenous group, age 27, mean peak HR are 79% and 83% of the age-predicted heart rate maximum during *SS* and *PS* trials respectively. These values place the riders' exertion in the vigorous, or high-intensity realm according to the American College of Sports Medicine Guidelines for Exercise Testing and Prescription (ACSM, 2006). During high-intensity physical activity, lactate production exceeds buffering capacity and accumulates in the blood (Kemp, 2004): due to the similar intensity level indicated by HR, a similar lactate response is not surprising. Furthermore, it would be reasonably expected that HR values would be greater during higher metabolic-cost activity (*PS* riding). However, a possible mechanism during *SS* riding was an increased catecholamine response to the stressor (Dishman et al., 2000), elevating HR to similar levels due to the significantly increased exertion indicated by RPE. As stated earlier, a majority of subjects appeared more tense during the *SS* trial. Whereas isometric muscle activity has the lowest metabolic requirement (Ryschon et al, 1997), whole body isometric contraction for postural maintenance and balance during switch riding, a possible mechanism that could have contributed to the similarity in blood lactate levels in each condition. Additionally, mechanical compression due to isometric

muscle activity causes increased intramuscular pressure, resulting in impaired blood flow and ischemia (Sjogaard et al., 1988), a mechanism that may have contributed to decreased lactate clearance in the present study. To illustrate this point, Gutierrez (as cited by Badier, 1994), noted that there was little change in venous blood lactate levels in resting rabbits during periods of ischemia.

Why do advanced level snowboarders who are good at recreational switch riding skid their switch-stance turns through a gated course? According to Dean (2013), it may be an attempt at minimizing the metabolic cost of movement, or perhaps even, the proprioceptive control of switch riding is not equally developed in the *SS*, creating longer-latency response of the nervous system than occurs in the preferred movement pattern. Raburn (as cited by Dean 2013) noted that when ischemia is applied to the body, the muscle spindles' ability to provide feedback is reduced: perhaps, then, the proposed ischemia associated with increased isometric tension and compression altered the riders' neuromuscular control system in the *SS*, thereby influencing the movement pattern. In addition, participants in the present study are not competitive racers or park riders: they may not be used to making standardized turns through a gated course as the turns were tighter than a recreational rider is likely to make during free riding.

Though years of experience may appear to influence the ability of certain riders, this measure does not predict performance. Those riders who reported 11 or more years of snowboarding experience did not finish the course faster or perform with greater degrees of board tilt in either stance. Interestingly, those who reported 11 or more years of snowboarding reported significantly lower RPE ($p = 0.005$) in the *SS* than those with

10 or fewer years but not the *PS* ($p = 0.14$). Therefore, years of experience may influence the stress associated with switch riding, however this may be attenuated with quality instruction in both domains. Of note is that snowboarding-days per year were not reported. Skill level is more likely due to days of riding per year, and the degree to which the rider seeks improvement.

Conclusion

Snowboard switch-riding results in increased time taken to complete a task and decreased board-tilt. Subjects riding in their preferred stance clearly had more control of carving turns, resulting in faster movement, increased inclination and resultant body-angulation, and therefore, possibly more concentric and eccentric muscle activity. Subjects riding switch skidded their turns, likely to reduce speed, and increase control around gates; this method of riding decreases board-tilt with respect to the slope and involves less concentric or eccentric muscle activity because skidding friction provides the braking component as opposed to muscular control. Executing a snowboarding task in the preferred movement pattern is less stressful in a practical manner, and allows for faster movement and more skillful carving turns. Regardless of stance position, snowboarding is a high-intensity activity when riding through gated turns: similar HR intensities and blood lactate levels reveal this, however, time, tilt and RPE values indicate that the intensity experienced by the rider is likely the result of different mechanisms. Instruction of novice snowboarders should focus equally on preferred and switch riding because it is important to work both domains as it could influence the overall riding

ability. Due to the bilateral transfer of physical skill that occurs with unilateral training, instruction that focuses equally on both stance positions will likely increase snowboarding skill more quickly than focusing on one movement pattern. Future research should involve longer courses with more gates, larger turn radii, and should include measurement of blood lactate five minutes after the completion of a course rather than 3 as in the present study.

Table 3.1 Descriptive data for study subjects

Subject	Age	Height	Weight	Yrs Exp	Gender
1	28	175	72.0	14	M
2	22	183	72.5	15	M
3	22	180	92.5	2	M
4	38	182	83.5	23	M
5	22	180	63.5	10	M
6	23	180	82.0	10	M
7	27	185	80.0	5	M
8	27	167	67.0	14	F
9	25	180	69.0	3	M
10	36	180	78.0	25	M
11	32	185	90.5	14	M
12	22	163	67.0	8	F
MEAN	27	178.33	76.46	11.92	XXXX
Std Dev	5.39	6.54	9.07	6.86	XXXX

Subject gender, age, height in centimeters, weight in kilograms, and years of experience along with mean and standard deviation.

Table 3.2 Blood lactate and RPE Ratings

Subject	LA PS	LA SS	RPE PS	RPE SS
1	3	3	3	4
2	2.6	1.9	0.5	1
3	3.1	3.4	4	7
4	2.8	2.1	0.5	3
5	3.4	2	4	5
6	1.2	0.8	3	4
7	1.7	1.6	2	3
8	1.6	1.7	1	2
9	1.6	3.8	0.5	2
10	2.1	2.9	0.5	0.5
11	3.6	4.3	0	0.5
12	1.1	1.8	1	5
MEAN	1.9	2.44	1.67	3.08
Std Dev	0.87	1.03	1.47	2.01
P value	0.33	XXXX	0.12	XXXX

Blood lactate (LA) in mmol, and Borg Scale RPE, mean and standard deviation in PS and SS trials, along with level of significance.

Table 3.3 Physical Fatigue, Mental Stress, and Level of Discomfort Ratings

Subject	PF PS	PF SS	MS PS	MS SS	LOD PS	LOD SS
1	0	0	0	1	0	1
2	0	0	0	1	0	0
3	1	1	1	2	0	0
4	1	0	1	1	1	0
5	0	1	2	1	0	0
6	1	1	0	1	0	2
7	1	1	1	2	1	2
8	0	0	0	0	0	1
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	1	0	0	0	0
12	0	1	0	2	0	2
MEAN	0.33	0.5	0.42	0.92	0.17	0.67
Std Dev	0.49	0.52	0.67	0.79	0.39	0.89
P value	0.31		0.08		0.67	

Modified stress index values for physical fatigue (PF), mental stress (MS), and level of discomfort (LOD), in PS and SS trials along with mean, standard deviation and level of significance.

Table 3.4 Heart rate, board tilt, and finishing times

Subject	HR HI <i>PS</i>	HR HI <i>SS</i>	TILT <i>PS</i>	TILT <i>SS</i>	TIME <i>PS</i>	TIME <i>SS</i>
1	164	169	35.60	27.66	21.38	23.41
2	144	169	44.50	48.90	13.74	14.36
3	157	175	35.18	28.55	18.26	25.90
4	167	180	48.05	41.75	12.07	15.40
5	177	162	45.95	40.78	13.51	15.47
6	135	132	41.79	46.36	13.43	15.07
7	135	137	47.89	40.74	16.40	19.33
8	154	155	42.65	35.51	17.87	22.40
9	158	155	47.15	40.70	15.93	16.47
10	160	168	47.48	45.56	14.60	17.66
11	130	159	44.34	43.66	16.31	15.40
12	XXXX	XXXX	43.36	34.66	17.47	21.80
MEAN	152.82	160.09	43.66	39.57	15.95	18.56
Std Dev	14.97	14.90	4.39	6.73	2.70	3.90
P value	0.048	XXXX	0.005	XXXX	0.001	XXXX

Heart rate in BPM, average of the maximum degrees of board tilt around each gate, and finishing time in PS and SS, along with mean, standard deviation and level of significance.

CHAPTER FOUR

CONCLUSIONS

This research project is the first of its kind examining stress and performance factors in snowboarders. Snowboarding is a highly competitive and popular sport with events including racing in the winter Olympics, half pipe and big-air events in the X-Games, and millions of recreational riders worldwide. While most research regarding the sport has focused on injury type and rate, as well as mechanical factors at the ankle joint, there is a lack of research with respect to the basic stress response during participation.

Finishing time increased significantly during *SS* riding, consistent with expectations, while the increase in RPE was practically significant, but not statistically different. Also consistent with the hypotheses, maximum degrees of board tilt decreased significantly during *SS* riding. The results of this experiment may have implications for instruction of novice snowboarders. When riding in the *SS*, there is a very marked increase in time to complete a snowboarding task, decreased board tilt angles indicative of lesser skill, and increased RPE. Given these results are obtained from advanced level riders, it is plausible that a similar, or greater change in these factors may occur in novice or beginning level riders riding switch. Furthermore, similarity in the heart rate and blood lactate response in both domains seem to indicate that a similar absolute intensity is achieved in both stance positions. One possible explanation for these results is that the general stress associated with riding in either domain is due to different mechanisms. In a rider's *PS* the intensity and resultant stress may be due to increased angulation of the

body due to increased board tilt and faster speed of travel. In the switch stance the intensity may be due to stress associated with performing in an abnormal fashion, and increased isometric stabilization and tension.

Due to these results, and the concept of bilateral transfer when learning a physical skill, it seems appropriate to recommend instruction that equally and immediately focuses on *PS* and *SS* riding in order for snowboarders to learn the skill more quickly than learning in one domain and then the other. Given that most injuries occur in beginners, if snowboarders are instructed equally in both domains and experience less stress when riding due to increased skill level, it is possible that injury rates may be reduced. During snowboarding events and styles such as big air, half-pipe, and park riding including free style riding, snowboarders often land in their switch stance. For individuals participating in these types of riding, and others learning the skill, practicing and learning snowboarding in both domains is a practical strategy for skill development and improved performance in both stance positions.

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APPENDICES

APPENDIX A

BORG CR10 SCALE FOR RATING OF PERCEIVED EXERTION

0	Nothing at all
0.5	Extremely weak (just noticeable)
1	Very weak
2	Weak (light)
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	
10	Extremely strong (almost maximal)
*	Maximal

APPENDIX B

MODIFIED MENTAL STRESS INDEX

Physical Fatigue	0-none 1-small 2-high
Mental Stress	0-none 1-small 2-high
Level of Discomfort	0-none 1-small 2-high

APPENDIX C

AASI NATIONAL CERTIFICATION RIDING STANDARDS FOR
LEVEL III INSTRUCTORS

LEVEL III	
The successful Level III candidate will demonstrate the ability to comfortably ride all terrain at the host mountain , up to and including:	<ul style="list-style-type: none"> • All but the most extreme terrain available • Small-to-medium freestyle features
At a minimum, the rider will be able to perform:	<ul style="list-style-type: none"> • Dynamic skidded, short- and medium-radius turns on black terrain • Switch dynamic skidded short- and medium-radius turns on black terrain • Skidded, short-radius turns in black bumps • Carved, large-radius turns on green trails • Dynamic carved, medium-radius turns on blue trails • Toe-to-toe side-carved, medium-radius turns on blue trails • Carved, medium and long-radius carved turns in bumps and black terrain • Freestyle elements, including jumps with a grabs and spins over small, man-made features, 180 airs, 360 airs, 50/50s on a rail with a "gap" entry, and board-slides on a box. • On transitional freestyle elements, including halfpipes, quarterpipes, steeper spine/hip jumps or similar natural terrain, demonstrate air at or above the lip, on both the toeside and heelside.

LEVEL III: Applied Movements
<p>Movements to be applied at Level III include flexion, extension, and rotation to affect the performance outcomes of twist, tilt, pivot, and pressure control in all riding tactics described in previous levels. The candidate will be asked to demonstrate flexion, extension, and rotational movements individually and in a blended fashion when performing the outcomes listed previously.</p> <p>At a minimum, the rider will demonstrate up-unweighting, down-unweighting terrain unweighting, and cross-over movements at a mature level. Cross-over is defined as the purposeful movement of the center of mass across the board by extending the legs at the initiation of the new turn, resulting in edge change and facilitating edge management. At this level the candidate will also demonstrate cross-under movements at a mature level. Cross-under is defined as the purposeful flexion of the legs to bring the board under the center of mass through the completion and into the initiation of the turn (resulting in edge change and edge engagement) and extension of the legs to direct the board out from under the center of mass (resulting in increased edge angle, or tilt, and an intentional increase in pressure during the control/shaping phase of the turn).</p> <p>At the request of the examiner, the rider will demonstrate: 1) the appropriate movement pattern for a specific outcome or movement pattern requested by the examiner, 2) the appropriate timing, intensity, and duration of movements relative to the desired outcome, and 3) an ability to maintain and regain reference alignments in all conditions and terrain listed previously (with the exception of freestyle outcomes). While riding, the candidate must demonstrate safety awareness through line choice, behavior, and the negotiating of traffic patterns on the hill. In addition, the rider will apply "cross-over" and "cross-under" movements at a mature level as determined by the examiner.</p>

APPENDIX D

SUBJECT CONSENT FORM

SUBJECT CONSENT FORM
FOR PARTICIPATION IN HUMAN RESEARCH AT
MONTANA STATE UNIVERSITY

TITLE: The Influence of Stance Position on Stress and Performance Factors During Snowboarding

You are being asked to participate in a research study on snowboard-related stress factors. You will be asked to snowboard through a standardized course in both preferred and switch stances, after which stress-related variables will be assessed. Although snow skiing has been studied extensively with respect to stress, mechanics, and physiology, there has been no research investigating these effects in snowboarders. The purpose of this study is to understand the stress associated with riding through a standardized course in the switch stance.

Investigator: David Connor & John Seifert, Montana State University

Procedures. If you agree to participate you will be asked to visit Bridger Bowl Ski Area on one occasion for a total of approximately one to one and a half hours. You will be asked to snowboard through a gated course with 18 standardized turns in your preferred stance, and in your switch stance. You will have the opportunity to perform a practice run in each stance for course orientation. Average heart rate will be analyzed with a Polar heart rate monitor to assess physical stress during each trial. Lower extremity rating of perceived exertion will be measured using a Borg RPE scale and will assess the level of stress associated with riding through the course. Mental stress will be assessed using a modified scale to assess the overall stress associated with each trial. Time to completion of each trial and maximum degrees of snowboard tilt will be analyzed for each of the trials using a Shadowbox inertial movement unit that gyroscopically measures degrees of deflection and time. Blood lactate will be analyzed with a Lactate Pro lancet: a finger stick method will draw one drop of blood at rest, and 3 minutes after each trial. Data will be analyzed by paired t-tests using a Bonferroni correction: significance will be placed at $p \leq 0.01$.

Time Commitment. Total time for your participation is about one to one and a half hours. You are free to discontinue this study at any time.

Confidentiality. Personal information and data will be kept in a cabinet in a locked office. Data used in analysis will be coded so that data sheets will not be identifiable.

Benefits. Results of this study will help us better understand stress factors associated with stance position during snowboarding. The results may help us understand factors associated with skill acquisition during snowboarding.

Compensation. You will be compensated for participating in this study. At the completion of the study you will receive a \$15 gift certificate for completing all trials.

Risks. There are risks to participating in this study. The risks of involvement in this study include discomfort and infection from the fingerstick blood sampling (a fingerstick blood sample involves a small stab to the finger to collect a drop of blood) sore or fatigued muscles from the exercise, and injury due to a fall. The level of risk for infection from blood sampling is very small. If complications do arise during this study, we can refer you to appropriate medical caregiver. Ski patrol will be available on the mountain as first responders in case of an accident. However, there is no compensation available from MSU for injury.

Questions. You are free to discontinue participation at any time without negative effects on your relationship with MSU or the researchers. Privacy and confidentiality of data will not be breached. If you have any questions, please ask us.

If you have any additional questions later, David Connor (630-363-1092) will be happy to answer them. Additional questions about the rights of human subjects can be answered by the Chairman of the Institutional Review Board, Mark Quinn, (406) 994-4707.

The Influence of Stance Position on Stress and Performance Factors During Snowboarding.

Freedom of Consent

I have been given ample opportunity to read this document in its entirety and to ask questions which have been answered to my satisfaction. I hereby consent to become a participant in this study knowing the health risks involved and that I may withdraw my consent at any time, for any reason. I also understand that project personnel may screen me from this study for any reason deemed appropriate.

AUTHORIZATION: I have read and understand the discomforts, inconvenience and risk of this study. I, _____ (*name of subject*), agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed: _____

Witness: _____

Investigator: _____

Date: _____