Monitoring Training-Induced Fatigue in Snowboard and Freeski Halfpipe Athletes

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Monitoring Training-Induced Fatigue in Snowboard and Freeski Halfpipe Athletes

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ATTESTATION OF AUTHORSHIP

ñI hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.ò

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ABSTRACT

Snowboard and freeski halfpipe are relatively new, skill-based high-risk alpine sports that have received very little attention in sport science research. It is prudent therefore to focus initial studies on gaining a more detailed understanding of the sport. Information on the type and amount of load and consequent fatigue from normal halfpipe training is an important first step and will help coaches to better plan training sessions and adapt them to current athlete energy states. Such information is also essential for sport scientists to effectively prepare athletes for and recover them from training and competition. This thesis considers the sensitivity of several common objective and subjective markers of training load and fatigue in order to gauge their effectiveness in inferring within- and between-day trends in load and fatigue during halfpipe training. Ten male and 14 female elite snowboard and freeski halfpipe athletes (21.8±3.3y, and 23.4±4.6y respectively) participated in a two week on snow training camp. Immediately prior to on-snow training sessions, subjectsô countermovement jump (CMJ) and level of perceived fatigue (LPF) were recorded. Post-session, CMJ and rating of perceived exertion (RPE) were recorded. A GymAware linear position transducer was used to measure mean power (MP), peak velocity (PV) and jump height (JH). Reliability was established using coefficient of variation, and a repeated-measures generalised estimating equations (GEE) model was used to examine relationships between variables within-day and between-day over the course of the camp. No significant relationships were found between subjective and objective variables when compared within-days. This suggested the variables may not be sensitive to changes in training load and fatigue from a day of halfpipe training. Significant relationships were found between post-session subjective and the next daysô pre-session objective score. Specifically, as the

subjective variables increased following training, the next dayôs objective variables reduced by varying factors. For example, a 1.00 unit change in RPE lead to a 0.01% and 4.68% change in PV and MP respectively, while a 1.00 unit change in RPE lead to a 0.04% and a 19.83% change in PV and MP respectively the next morning. When considering subjective and objective variables in isolation, subjective LPF was observed to increase over the course of the camp despite rest days, while neither of the pre-session objective CMJ variables exhibited significant trends. CMJ variables tended to increase by 2.0 ï 5.6% after a dayôs riding. It was concluded that traditional RPE scales used in conjunction with subjective fatigue ratings and/or MP and PV measurement using GymAware LPT can be useful tools to assist coaches and scientists in prescribing training and monitoring fatigue over time. Some evidence of overreaching was found in this study and longer term monitoring of these objective and subjective variables may assist in alerting to signs of overtraining. Further research is required to determine methods of monitoring acute effects of fatigue from halfpipe training.

CHAPTER 1: INTRODUCTION

Purpose Statement

The purpose of this thesis was to consider and then build on the scientific and practical coaching knowledge surrounding the training load (TL) that snowboard and freeski athletes are subject to during normal halfpipe training. To this end the intent was to investigate the sensitivity of several objective and subjective measures.

Initially, within this these, the literature concerning the concept and evaluation of load and fatigue is discussed with respect to the high risk, skill based environment of halfpipe. Secondly TL and its resultant fatigue is experimentally examined during a two week on-snow training camp involving Elite halfpipe riders from varying nations.

Aims Of Thesis

The aim of this thesis was to quantify the TL during normal halfpipe training and compare this to objective neuromuscular and subjective psychological fatigue inference tools, in order to identify whether fatigue markers are sensitive to TL. Specific consideration was given to the skill based, high risk alpine environment in which these athletes train as well as to the methodological considerations required of field based observation of this cohort.

Identifying then validating tools for monitoring halfpipe TL and providing practical recommendations to coaches and sports scientists was an important reflective outcome of this early research.

Significance Of Thesis

This thesis contributes to the scientific awareness and practical understanding of TL and consequent fatigue pathways halfpipe athletes are subject to during training. The introduction of science into this sport is an important part in its professionalisation and development. The findings from this thesis provide coaches and practitioners with current scientific and evidence based information in the area of TL and may increase their understanding of the various forms of fatigue relevant to their sport. Furthermore, this thesis provides the framework for on-going monitoring as well as direction and recommendation to future research with this cohort and training environment. Additionally, given the newness of this sport and research into it, enabling coaches and athletes to get used to the role and presence of sports scientists was an important adjunct of this research.

Thesis Outline

The main body of the thesis is presented through three chapters. Chapter Two, which is presented in two parts, provides a review and discussion of the literature surrounding halfpipe TL (Part I) and fatigue (Part II). These sections have been combined and subsequently submitted to the Strength & Conditioning Journal. Chapter Three includes the research from an observational investigation into the effectiveness of using markers of fatigue and TL to monitor within- and between-day trends in halfpipe fatigue and TL. Chapter Three has been submitted to the International Journal of Sports Science and Coaching. Chapters Two and Three are both presented in the format for the journals to which they have been submitted. Chapter Four provides an overall general summary and some further reflective thoughts specific to practitioners and coaches working with this cohort. The use of this format means there may be some repetition between the introductory and summary sections of those chapters, and within the thesis as a whole. For consistency, the references have been standardised to APA 6th Edition and one final reference list for the complete work is included at the conclusion of the thesis.

CHAPTER 2.1: LITERATURE REVIEW.

UNDERSTANDING LOAD AND FATIGUE IN FREESKI AND SNOWBOARD HALFPIPE – A REVIEW. PART I OF II: MONITORING LOAD.

Abstract

Snowboard and freeski halfpipe are skill based, high-risk, alpine sports with high injury rates but limited published research. Information on the type and amount of training load (TL) performed and consequent fatigue from halfpipe training is important for coaches in order for them to plan training sessions and adapt to athlete energy levels, and for sport scientists to effectively assist the athletes in preparing for and recovering from training and competition. In a sport where limited research exists, initial studies should focus on observing normal training sessions and gaining coachesô trust in sports science. Given the variability in observational studies, scientists require stable and reliable methods of observing and measuring TL in halfpipe. As part one of a two part series, this paper explores the concept of TL in halfpipe and suggests several methods of its monitoring in the field. A follow up paper discusses the presentation of fatigue and provides several possibilities for its measurement in the field for halfpipe coaches and sport scientists.

An Emerging Performance Sport – The Training Context

Snowboard and freeski halfpipe are skill based, high risk, alpine sports where high force is required to be produced and withstood over very short time periods during take-off and landing. The trough-like halfpipe feature can be either entirely made of snow or have an earth base over which the snow is shaped (see Figure 1). Full ñrunsò last around 20-30 seconds where the athlete performs 6-8 ñhitsò where various manoeuvres (tricks) are executed. The multifaceted nature of halfpipe is both intriguing and confounding to the sports science team trying to devise optimal periodised training and recovery (Gabbett, 2004; Gabbett & Domrow, 2007). While research into alpine skiing is common, we know so little about halfpipe that often the researcherôs role in assisting athletes/coaches is based on anecdotal evidence only (Turnbull, Kilding, & Keogh, 2009).

Figure 1. Typical halfpipe with the flat base leading into the curved transition into a vertical vall and then lip, before flattengin out onto the deck of the pipe. An athlete can be seen performing a trick.

General halfpipe training sessions involve basic skills and fundamentals, trick progression and/or trick and run refinement. Typical training sessions can involve up to 20 runs in the pipe and last anywhere from 1-4 hours. Athletes usually hike back to the top after their run, however more recently lifts (chairlifts/poma) have become available on the side of halfpipes. Occasionally teams will have access to snowmobiles to return athletes to the top. Hiking uphill for the next run can take up to 5 minutes and involves carrying a board in high altitude, alpine conditions. Lifts and snowmobiles greatly reduce the overt energy expenditure sustained through hiking, allowing more runs to be performed each day. While arguably increasing the potential for skill development the increased energy expenditure and consequent fatigue of more and more runs each day could have a negative effect on training quality and/or increase the risk of acute and chronic injury.

Little is known regarding differences in overall TL if the athletes hike or are carried to the top of the course, as the reduced number of runs performed when hiking might be offset by the physical challenge of hiking. Competition usually only includes a training window of around 20-30 minutes where 2-5 runs will be available. Following training is a qualifying round of 2-3 runs then, based on success, the progression to finals which are usually another 2-3 runs. Throughout the calendar year gaining quality on-snow training time is paramount. With glacier training in the northern hemisphere summer, athletes are rarely off snow for more than six weeks. While this provides plenty of time to practice tricks, the downside is that very little time may be dedicated to improving physiological function or to recover from the previous yearῷs training and competition.

While specific reference to the energy system will be presented below, it is important to note that coaches and scientists often argue over the energy systems involved in halfpipe. Although a run only takes 30 seconds (indicating a predominance of anaerobic metabolism) the hiking component, and the sheer volume of time spent training (3-4 hours 4-6 days a week) will require a level of aerobic efficiency.

Furthermore, despite the access to lifts during training, competitive environments still generally require athletes to hike during training.

Clearly more information is needed on the *loads* elite halfpipe athletes encounter and the *fatigue* developed from such loads. These two areas need to be defined separately as they have different implications for coachesô planning, training prescription and recovery. Identifying load requires quantifying how hard and how long a session is while identifying fatigue concerns the effect of this load on the athlete relative to their ability to subsequently train effectively. This paper will consider the literature surrounding the quantification of load as it relates to the training environment of halfpipe. A subsequent review will address the resultant fatigue of such halfpipe training.

Research In Halfpipe

While literature surrounding quantifying fatigue and TL is extensive, an Ovid literature search of ósnowboardô ófreeskiô, and óhalfpipeô (spanning 1990 to present) yielded 191 hits, only four of which were articles discussing performance variables, the remainder targeting injury prevalence and mechanics. Of the four performance related halfpipe articles identified, only three (see Table 1) utilised the halfpipe training context and all involved small sample sizes and closed population samples which may not be generalisable to elite populations (Arruza, Telletxea, Azurza, Balague, & Brustad, 2005; Hilfiker, Hubner, Lorenz, & Marti, 2007; Kipp, 1998; Platzer, Raschner, Patterson, & Lembert, 2009).

Table 1. Summary table of research in performance halfpipe.

Author	Subjects	Methods	Data	Results
Kipp (1998)	N=3 National Team (Halfpipe)	Observation during normal training,	Heart Rate Blood Lactate	Maximum heart rate = 92% Blood lactate = 2.9mmolL^{-1}
Arruza (2005)	N= 5 National Team (Halfpipe)	Controlled incremental field protocol	Heart rate, Fatigue and Intensity to failure	Training demand related to heart rate (r=0.74), Fatigue (r=0.84), and Intensity (r=0.87) respectively p=<0.01
Platzer (2009)	N=37 World Cup (24) European Cup (9) athletes (Halfpipe, Boarder cross, Paeralell, Big Air)	Multiple testing protocols:	Strength, Speed, Power, Stability, Endurance	Aerobic fitness the best predictor of World Cup points in women (r=0.73,p<0.01), For halfpipe specifically they found menôs results correlated well to countermovement jump performance (r=0.78 p<0.05

Kippôs (1998), observational field study of basic physiological variables was the earliest published paper found. They provided a graphical representation of one athleteôs typical mean heart rate (HR) trend over the course of a training session. Kipp (1998) identifies the clear pattern between hiking the pipe (~160bpm), recovering from the hike/preparing to drop in (~120-130bpm), and actual pipe riding (~184bpm). Arruza et al.ôs (2005), incremental maximal experiment examining the relationship between self-reports of fatigue, exertion and heart rate involved athletes hiking a pipe at greater distances which required them to increase their hiking speed until exhaustion. Such a manipulated training session structure, similar to a cycle ramp test, allows variables to be controlled but is unlike any training environment seen in halfpipe. They reported high correlations between fatigue and intensity (r=0.96) but lower correlations between fatigue and heart rate (r=0.71), and fatigue and perceived exertion (r=0.67) when measured concurrently. From these results they reported that the variables of level of perceived fatigue (LPF) and rating of perceived exertion (RPE) are reliable measures for field based measurement of fatigue and intensity. Platzer et al. (2009) investigated physical ability versus sport capability measured via international ranking, concurrently measuring validity & reliability of several field tests with snowboard athletes. They concluded that physical ability appeared to be more strongly related to World Cup ranking and performance in women than men, and in snowboarder-cross and halfpipe compared to other disciplines (Platzer et al., 2009). They cite long seasons, multiple events, high altitude training environments, and psychological factors as the major stressors which being physically fit can influence. Others have presented papers on kinetic and kinematic factors of skiing and snowboarding however, none used halfpipe or elite level riders and are either discussion documents or theoretical models (Delorme, Tavoulris, & Lamonatagne, 2005; Hart, 2002; O'Shea, 2004; Wu, Igci, Andreopoulos, & Weinbaum, 2006).

While the depth of performance literature is limited, clinical, epidemiological and prevalence research has provided more insight into the kinetics and kinematics of injury with respect to the difference in ability level of snow sports athletes (Bindner & Greiger, 1999; Myer, 2006; Platzer et al., 2009; Tarazi, Dvorak, & Wing, 1999; Yamakawa, 2001; Zacharaopoulos, 2004). Yamakawa and colleagues, (2001) for example, in their retrospective review of 12 years of snowboard jumping and spinal injuries from 1988 to 2000 noted that snowboard landings involve rotated and anteriorly flexed spinal postures, which greatly increase spinal load. Several other studies reported that the primary mechanisms for skiing and snowboarding injury are jumping and impact, rather than the falling and torsion injuries predominant in skiing (Bindner & Greiger, 1999; Tarazi et al., 1999; Yamakawa, 2001). These same authors indicate that impact and landing injury was more prevalent and severe in advanced riders due to the increased height they gain relative to novice riders (Bindner & Greiger, 1999; Tarazi et al., 1999; Yamakawa, 2001). In their extensive review of World Cup ski and snowboard injuries, Florenes, Nordsletten, Heir, and Bahr (2012) identified that around one third of all alpine, freeski and snowboard competitors sustain an injury that takes them out of competition for more than a few days. Most concerning was the fact that one third of all the injuries sustained were identified as severe, (i.e. requiring more than four weeks off snow).

Understanding And Monitoring Training Load

Training load is the product of intensity and duration of training (Borresen & Lambert, 2008). Many authors find the idea of being able to quantify training by a single measurable unit of load appealing. This method of training quantification is common especially among endurance sports and involves being able to reliably monitor both training intensity and duration (Borresen & Lambert, 2008; Gabbett, 2004; Gabbett & Domrow, 2007; Morton, 1997). There are many issues with this approach however, particularly for a sport like the halfpipe. Estimating duration for example assumes that the time on task is the only period where fatigue is produced, and does not account for activity outside of the ótrainingô session such as traveling to work/practice, photo shoots, media commitments and daily life tasks (Borresen & Lambert, 2008; Gabbett, 2004; Gabbett & Domrow, 2007; Morton, 1997). Also the various methods of accounting for intensity contain their own issues. Different movement contexts, for example steady state endurance work versus intermittent impact based sports such as halfpipe or rugby, add another layer of complexity and potential for error. Despite the complexity of monitoring the training context, there exists a need for a greater understanding of session structure and intensity in halfpipe in order to accurately understand the resulting TL.

The dose-response relationship provides a good medium in which to view fatigue and fitness in sport. Physiological sports (those relying on more discrete specific elements of strength, speed, power or endurance) require fatigue and overload in order to super-compensate and develop these elements further. These sports are referred to as high fatigue-multipliers (Morton, 1997). This perspective identifies the skill based sport of halfpipe as a low fatigue multiplier sport in that the positive adaptation effects of fitness may be relatively less important than the negative effects of fatigue on skill acquisition. From this perspective, there exists a dose-response threshold beyond which injury risk increases, and skill development may be increasingly ineffective (Avalos, Hellard, & Chatard, 2003; Drinkwater, Galna, McKenna, & Hunt, 2007; Gabbett & Domrow, 2007; Morton, 1997).

Without an understanding of load the incorporation of fatigue measurement will remain un-validated considering the numerous variables within the training context. However, the separation of training sessions into various levels of intensity is an important step in educating athletes and coaches about season and session planning, about individual responses, and about the athlete energy states required of safe and effective training.

When attempting to understand the load characteristics of sport performance Cairns and colleagues (2005), suggest that the *subject selection, fatigue quantification, and fatigue protocol* need to be clearly defined and controlled. Fatigue protocols involve quantifying and controlling the load in order to ensure a stable platform on which to assess the resultant fatigue variables. Considering the challenging, variable environment of halfpipe, and the requirement for athletes to individualise their training, observational studies of load appear prudent initially. This paper outlines two of the more common methods of measuring intensity which we feel would be useful in developing coach and athlete awareness of TL in Halfpipe. These methods have previously been used by Kipp (1998) and Arruza et al., (2005), but only to infer intensity and only in isolated scenarios, not over long periods. Utilising these measures over longer timeframes and combining them with measures of training duration may provide greater insight into the energy systems required for sustaining high performance halfpipe training. This section outlines the methodological issues coaches and practitioners should consider when implementing them in the field.

It is important to note that there are many other methods of monitoring training intensity in the field. For example portable VO_2 systems and blood lactate analysis has been used by Alpine ski racing in the past (Turnbull et al., 2009). The following measures have been chosen over these others because they allow freedom of movement and unrestricted, independent training by the athlete and coach. These two methods are also some of the most widely used and reported methods of load assessment.

a) Heart Rate

Monitoring HR appears commonplace in research using steady state endurance athletes. There are numerous devices for monitoring HR. However, once the raw value has been collected the derivation of useful information for high intensity sport is essential. The validity of HR as a measure of intensity/load during intermittent and high intensity work is somewhat questionable. This is because HR increases disproportionately during resistance training and high intensity exercise, which means stable cardiac responses required for HR monitoring are not maintained (Borresen & Lambert, 2008). In order to allow for a more specific evaluation of training intensities several methods have been used to separate heart rate into intensity zones and then relate these to the duration spent in specific zones (Impellizzeri, Rampinni, Coutts, Sassi, & Marcora, 2004).

Two of the more commonly reported methods for doing this specific evaluation are the Summated Heart Rate Zones (SHRZ) and Training Impulse (TRIMP) methods (see Equations 1 and 2 below) (Borresen & Lambert, 2008; Foster et al., 2001). The SHRZ method separates intensities by percentage of the maximum. The TRIMP calculations of zones are simplified to below Ventilation Threshold (VT), between the VT and the Respiratory Compensation Threshold (RCT) and above the RCT (Borresen & Lambert, 2008). In each case, the zones are multiplied by a coefficient relative to the intensity of the zone (weighing high intensity greater than time spent in low intensity) in order to equate time spent in the different zones to the same unit of measurement.

Equation 1: Summated HR Zones:

- (D_z1 x 1) + (D_z2 x 2) + (D_z3 x 3) + (D_z4 x 4) + (D_z5 x 5).
    - D_z = Duration in Zone. Zone 1 = 50%-60% of MHR, Zone 2 = 60%-70% of MHR, Zone 3 = 70%-80% of MHR, Zone 4 = 80%-90% of MHR, Zone 5 = 90%-100% of MHR (Borresen & Lambert, 2008).

Equation 2: TRIMP:

- Men: Duration (min) x (HR_{ex} ï HR_{rest})/(HR_{max} ï HR_{rest}) x $0.64e^{1.92x}$
- Women: Duration (min) x (HR_{ex} ï HR_{rest})/(HR_{max} ï HR_{rest}) x $0.86e^{1.67x}$
    - Where e ï 2.712, x = (HR_{ex} ï HR_{rest})/(HR_{max} ï HR_{rest}). HR_{rest} = Average HR during rest, and HR_{ex} = average HR during exercise (Borresen & Lambert, 2008).

Borresen and Lambert (2008) found that using interval based circuit training in a resistance training setting, the TRIMP and SHRZ methods were highly correlated (r=0.98, 98% CI 0.96 to 0.99). Moreover the SHRZ method correlated well with RPE (r=0.84, 95% CI 0.70 to 0.92) across various intensity levels.

There are however several issues with heart rate methods which need to be taken in to consideration when using them within intermittent intensity state, high injury risk and competition environments. For example the zone factors needs to be validated for different populations (Borresen & Lambert, 2008). Furthermore, the fixed zones mean that intermittent exercise crossing zones may result in calculation error. For example, mean heart rates of 69% vs 71% maximum means very different things in the SHRZ methods while in reality they may be very similar in terms of physiological cost and fatigue outcome (Borresen & Lambert, 2008). The time spent below 50% in the SHRZ method is also not accounted for. This is pertinent to halfpipe since athletes are often standing in queues or sitting on chairs open to the elements but with HR continuing to drop. An individualӳ expression of heart rate can be affected by numerous factors: perceptions of physical effort; hormonal and substrate concentrations; female menstrual cycle; personality (i.e. introverts vs extroverts); increased ventilation rate; environmental factors (including weather, pipe conditions); and the athleteӳ psychological state as influenced by investigation team, significant others, type of training session, time constraints (Borresen & Lambert, 2008). Confounding this, over-trained athletes may elicit lower HRs than normal for a given intensity, giving a false indication of low work rates.

Further issues with HR monitoring include the requirement of finding maximum heart rate for each individual. Considering the significant variety of training ages and states of most halfpipe teams, the use of weighting factors and calculated maximum heart rates is questionable unless each is validated for each individual it is being used for (Borresen & Lambert, 2008). Because of these limitations, using any method to compare across individuals will contain greater uncertainty than comparing within an individual (Borresen & Lambert, 2008). However, if the above mentioned issues are considered, and individualsô maximums are validated, the ease of monitoring HR using modern devices does permit regular and consistent monitoring of this variable. Used in conjunction with other forms of load quantification, HR should remain the staple variable of load measurement.

b) Rating of Perceived Exertion (RPE)

It has been shown that athletes are inherently aware of the physiological stress they are under during exercise (Borresen & Lambert, 2008). It follows therefore that the easiest and most reliable measure of intensity may be to simply ask the athlete. The RPE scale is widely used to assess session intensity. The RPE has historically been a 20 point scale (the Borg Scale) but has recently been shortened to a simple 10 point scale identified in Figure 2 (Borresen & Lambert, 2008; Foster et al., 2001).

Unlike HR methods which have to be adjusted to compare across individuals, RPE have been shown to be easily adapted to anyone by a simple explanation of the scale system relative to their age and sport (Borresen & Lambert, 2008; Foster et al., 2001). The timing of application of the RPE is important, due to the tendency to focus on the last period or the most intense/uncomfortable part of the session (Borresen & Lambert, 2008). If the current rate of exertion is needed then direct application is simple (i.e. how hard are you working now?). However if a judgment of the entire session is required, then delaying the rating for a half hour is likely to reduce the focus on very high or very low periods of activity. This delay will allow a more accurate recording of the entire intensity and be more indicative of the fatigue they feel from the session (Borresen & Lambert, 2008; Foster et al., 2001).

"HOW HARD WAS YOUR SESSION?"

0	*Rest*
1	*Really easy (Very,very easy)*
2	*Easy*
3	*Moderate*
4	*Sort of hard (somewhat hard)*
5	*Hard*
6	
7	*Really hard*
8	
9	*Really, really hard*
10	*Just like my hardest race ever (Maximal)*

Figure 2. Rating of Perceived Exertion (RPE) scale as reported by Borresen and Lambert (2008) (In brackets are the scales used by Foster (2001)).

Foster and colleagues (2001), found the RPE method to be a valid and reliable method for evaluating the intensity of aerobic exercise relative to the SHRZ method, reporting that the intraclass correlation coefficient was 0.90 and 0.75 for RPE and SHRZ respectively. They found that while the SHRZ method gave lower scores than that of the RPE, this pattern was consistent for several different forms of exercise including intermittent high intensity work and simulated basketball game play. Gabbett and Domrow (2007) found that during simulated rugby match play lactate and RPE were highly correlated (r = 0.86), as were HR and RPE (r = 0.89).

One thing to note, however, is that the influence of very high intensity work, such as sprints and plyometric activity, has been reported to result in higher RPE scores relative to the HR (Borresen & Lambert, 2008). For example, Impellizerri et al. (2004) found varying correlations of r=0.50 and r=0.85 for individuals in team training in soccer players involving sprint and plyometric type activity. The inclusion of maximal ratings therefore need to be considered carefully if found in halfpipe settings.

RPE is useful in recording acute training related fatigue, and is also effective in monitoring more chronic responses to training. For example, RPE may be more sensitive to accumulated fatigue and over reaching than heart rate or hormonal markers given the aforementioned dampened HR response to overtraining (Borresen & Lambert, 2008). For long term monitoring, monotony and strain are two supplementary variables that can be identified through RPE (intensity) and training duration. Monotony is calculated by dividing the daily mean TL (intensity x duration) by the standard deviation of the TL. Further, the product of monotony and weekly training load (summated daily TL across the week) is identified as strain (Foster, 1998; Rietjens et al., 2005). Short term increases in strain and monotony have been suggested as being indicative of overreaching and the beginnings of overtraining (Foster, 1998; Rietjens et al., 2005).

Conclusions, And Practical Recommendations

Despite halfpipeȇs inclusion as an Olympic sport where medals are fiercely contested and financial investment by nations can be substantial, published material on halfpipe training is currently limited. Understanding the training context and the load halfpipe athletes are under is important for effective off-snow preparation, on-snow training session prescription and long-term season planning.

The sports scientists challenge in developing these skills in halfpipe coaches lies in our ability to identify and monitor load and fatigue indicators and effectively report these back, linking their expression to performance. Practitioners intent on developing their sport specific knowledge need to understand the intensity and makeup of different training sessions before approaching the measurement and monitoring of fatigue, otherwise recommendations on training prescription will be without context. Training load presents an ideal medium for understanding and monitoring training without interrupting the training environment.

Due to the various and as yet unquantified stressors in the training environment, such as risk, altitude and environmental conditions, and the stop-start nature of halfpipe, a holistic measure of intensity may be of most use to coaches and sport scientists. Regardless of the mechanism used to measure load during a session, such measures need to be sensitive to the time spent in different intensity zones of hiking, lift time, riding time, and coaching time.

From initial observation the incorporation of a multi-factorial approach to the assessment of load and fatigue could be of use in developing awareness amongst coaches and athletes, and in developing a more stable and planned coaching environment from which future scientific investigation may prevail. Specifically, it is recommended to use observational research methods which do not interrupt skill acquisition environments of the coach-athlete. Methodologies should include physical and psychological tools to account for the risk and environmental context, not just the movement and energy systems being utilised. Considering the multitude of factors affecting athletes and data collection methods, it is recommended that where possible observation and data collection occur over as long a time frame as possible, rather than over short intense periods such as training camps.

CHAPTER 2.2: LITERATURE REVIEW.

UNDERSTANDING LOAD AND FATIGUE IN FREESKI AND SNOWBOARD HALFPIPE – A REVIEW. PART II OF II: MEASURING FATIGUE.

Abstract

Snowboard and freeski halfpipe are skill based, high-risk, sports where coaches and sports scientists must balance the need for training to progress with the risk of serious injury as a result of various fatigue outcomes. When considering skill and risk sports, definitions of fatigue must be inclusive of its various forms and expressions from physiological, psychological and biochemical domains, as each impacts performance in different ways. Isolating the fatigue response from the TL is an important process for coaches and scientists because individual athletes will respond differently with varying degrees of each form of fatigue from the same TL. This review provides a follow up to a previous paper discussing the monitoring of TL. Herein we explore the concepts and presentation of fatigue in halfpipe, suggesting several methods of monitoring fatigue useful to coaches and sport scientists in the field.

An Emerging Performance Sport – The Training Context

Once an understanding of the training context of a sport is obtained, it is important sport scientists attend to the athletesô reaction to such training, i.e. the fatigue response to a TL. The terms training load and fatigue are often used interchangeably, in that if the load is high, fatigue is assumed to also be high. However these two monitoring tools do need to be considered independently especially in intermittent, skill-based high-risk sports where overt energy expenditure may be low but its impact high. Moreover where endurance sports may utilise a single load figure, the multifaceted nature of skill-based and high-risk sports include an amount of psychological stress typical intensity scales may fail to effectively address. Multiple energy systems are involved in skill-based high-risk sports and as such the process of measuring fatigue resulting from training needs to be inclusive of these systems.

Numerous studies have reported the strong associations between TL, fatigue and increased risk of injury. Chappell et al. (2005) in their review of fatigue in stop jump tasks, and Gabbett and colleaguesô (2005, 2007) in their observational studies of rugby league game-play identify such trends, especially late in the day and session. Placing this in the halfpipe context: the complexity of the tricks performed; the amplitude (height above the halfpipe lip) which riders reach out of the halfpipe; as well as the long seasonal demands of competitive halfpipe, all contribute to a high risk of injury (O'Shea, 2004; Tarazi et al., 1999)**.**

In halfpipe it is often a subjective call by both coach and athlete on when to end a session rather than relying on any pre-set physiological or time-based marker. Given time a coach builds a strong understanding of their athlete, their abilities, mental focus, goals, reactions to certain training stimuli and ideal performance state. For learning and perfecting new tricks, and to reduce risk of injury, both athlete and coach argue strongly that the athlete needs to be in the ózoneô (a concept similar to óflowô where an athlete is highly motivated and attuned to the trick they are working on) in order for a session to be truly valuable (Engeser & Rheinberg, 2008). The decision to end a session may therefore be made based on poor conditions or a decrease in performance (e.g. falling several times on a low level trick), taking excessively long to hike and strap in, or simply the athlete ónot feeling itô and falling out of the ózoneô (Chappell et al., 2005). Any requirements for standardising load therefore need to accommodate for the idiosyncrasies of athletesô performance condition and encourage athlete and coach agreement on cessation of a training session (Engeser & Rheinberg, 2008; Kajtna, Tusak, Baric, & S., 2004). Using markers of fatigue to quantify the session may be more effective than the fulfilment of a number of runs or time on task, especially until coaches and athletes buy into more detailed scientific investigations on-snow. Following this, it seems prudent that initial investigations of halfpipe do not interfere with coachesô training plans and instead merely observe outcomes in order to provide evidence for change (Foster, 1998; Stewart & Hopkins, 2000).

Research In Fatigue

Studies of fatigue have predominantly been within endurance sports where the specific energy system is more easily identified and valid and reliable tests have been well established (Filaire, Bernain, Sagnol, & Lac, 2001; Petibois, Cazorla, Poortmans, & Deleris, 2003). Investigation into skill based, team and collision sports has been limited to descriptive changes in match play and win loss results, and directed to biochemical or psychological markers of the extreme of óovertrainingô (Foster, 1998; Gabbett & Domrow, 2007). Many studies are very specific in nature, with little information directly usable by coaches, especially with respect to manipulating training environments to control load.

Throughout the literature there are multiple definitions of fatigue with respect to its timing, presentation and influence. Much fatigue research centres on physical capacities, as have definitions of fatigue (Cairns et al., 2005; Gandevia, 2001; Presland, Dowson, & Cairns, 2005). For example Presland et al., (2005), in their investigation into central fatigue responses, and Cairns, Knicker, Thompson and Sjogaard (2005), in their discussion of methods used for studying neuromuscular fatigue, refer to fatigue as an acute reduction in force, power or performance. However, following the application of central fatigue and tiredness research into skill and concentration activities (drivers and pilots), fatigue science is becoming increasingly aware of the effect of psychological aspects and self-reports of fatigue on both skill and physiological performance (Marcora, Staiano, & Manning, 2009; Morgan, Brown, Raglin, O'Connor, & Ellickson, 1987; Morton, 1997; Rietjens et al., 2005). On this basis, for the purposes of this discussion fatigue will be defined as a feeling of tiredness and a lack of focus as a result of physical and/or mental work, demonstrated as an inability to perform a session at the required level after intra or intersession recovery (Kuipers, 1998; Morgan et al., 1987; Morton, 1997; Strojnik & Komi, 1998).

It is important that fatigue be defined relative to exhaustion or overtraining in the performance context. Exhaustion is the voluntary termination in motor drive distinguished by the acute inability to continue to perform at the level demanded and is associated with high ratings of perceived exertion (Presland et al., 2005). Overtraining on the other hand is the chronic expression of the fatigue and exhaustion responses (Kuipers, 1998; Morton, 1997). Some authors describe an intermediate state prior to overtraining called overreaching ï which can be thought of as an extended fatigue but one which can be reversed given sufficient rest and replenishment, whereas overtraining may require more extensive rehabilitation (Kuipers, 1998; Rietjens et al., 2005).

Many investigations into fatigue and the extremes of overtraining have centred on endurance sports which typically build intensity and volume towards a taper prior to a pinnacle event. Little is written about the risk of overreaching and overtraining in team sports involving at least one game per week across a season, nor the high load of training and risk that skill based sports, such as halfpipe, require (Filaire et al., 2001).

The use of laboratory compared to field based studies is a contentious issue, each providing compromises in ecological validity or reliability (Cairns et al., 2005; Thorlund, Michalsik, Madsen, & Aagaard, 2008). Laboratory studies provide highly reliable and repeatable environments for cyclic sports and specific movements. While allowing scientists to specifically pinpoint and quantify mechanisms of fatigue, laboratory environments are constrained by the sport specificity of complex whole-body tasks. On the other hand, field based performance settings provide the ability to measure global central fatigue and some peripheral fatigue contributions but are limited in their ability to target the causal cellular mechanisms behind performance decrement (Cairns et al., 2005). Furthermore the hazardous and uncontrolled environment of field testing makes reliability and reproducibility of testing in these environments fraught with uncertainty. For complex sport environments, some researchers attempt to recreate sport movements in the laboratory to provide a standardised work load or movement pattern in order to accurately gauge how these are affected by simple factors such as volume or intensity. (Chappell et al., 2005). Because of the newness of halfpipe to performance realms, little data exists from which to provide directions for such a set protocol. Moreover, rarely do simulation activities involve the intensity and freedom of normal training or competition and they certainly do not involve the mental focus or arousal levels of training under the high risk and complex motor control requirements seen in halfpipe (Cohen, Kamarck, & Mermelstein, 1983; Kajtna et al., 2004). Until considerably more research into the complexities of the environment and movement context of halfpipe is conducted, there needs to be another method to standardise the fatigue protocol by which TL and fatigue research may be administered. Furthermore until a structured fatigue protocol exists, observational methods using known fatigue variables will be required to be used over long durations. One-off assessments may be unable to explain the multitude of effects on the different energy systems which halfpipe targets. To this end the following section outlines the mechanisms of fatigue and their performance effects in the halfpipe context, suggesting methods of how to measure these effects and provide recommendations to practitioners.

Understanding And Measuring Fatigue

a) Neuromuscular

Neuromuscular fatigue is becoming a common term in coaching and sport science practice. While grouped together for ease, it is important that the presentation and pathology of neural and muscular fatigue are considered separately (Gandevia, 2001; Knicker, Renshaw, Oldham, & Cairns, 2011; Presland et al., 2005). One means of doing this is to identify neural as central and muscular as peripheral fatigue. Both result in altered muscle control, but do so via different cause and effect pathways. Peripheral causes of muscular fatigue involve changes at, or distal to, the neuromuscular junction (NMJ). Such changes cause disruption to energy supply resulting in a lack of oxygen, lactic acid accumulation, electrolyte loss and dehydration (Ross, Leveritt, & Riek, 2001; Strojnik & Komi, 1998). From a performance perspective, peripheral fatigue results in a reduction in the ability to produce and withstand forces required for takeoff and initiation of tricks, and for landing and protecting joints during crashes despite messages to do so coming from the central nervous system (O'Shea, 2004). Central fatigue is identified through spinal and/or supra-spinal disruption to afferent and efferent pathways, and is thought to be the earliest expression of overtraining related fatigue problems (Rietjens et al., 2005). From a performance perspective, disrupted afferent pathways are responsible for reduced proprioception during fatigue while disrupted efferent pathways result in delayed muscle contraction responses, both of which place the lower limb at increased risk of injury in the halfpipe setting (Cairns et al., 2005; James, Dufek, & Bates, 2006; McLean et al., 2007; Presland et al., 2005; Strojnik & Komi, 1998; Thorlund et al., 2008).

Identifying the source of fatigue in the field is challenging. Because of this the general presentation of central and peripheral muscular fatigue is commonly referred to as neuromuscular fatigue. Directly measuring neuromuscular fatigue has limited options due to the precision needed to quantify neural pathways and because of the invasiveness of the more common procedures. Obviously intricate techniques such as superimposed tetanic stimulation or electromyography (EMG) methods may not be feasible for regular field based monitoring, and are possibly too intricate for use in a performance setting where so many non-physiological variables may exist (Gandevia, 2001; Presland et al., 2005).

The most simple and commonly used field tests of neuromuscular fatigue focus on functional activities such as jumping, landing, or absorbing impact (Augustsson et al., 2006; Cormack, Newton, McGuigan, & Dolyle, 2008; Santello, 2005; Santello, McDonagh, & Challis, 2001). Cairns and colleagues (2005), identified that the key variables most relevant to fatigue in many performance settings are muscle force, extent and velocity of muscle shortening, and power. The fatigue response may reduce propulsive forces and increase ground contact forces on landing. This ultimately reduces performance quality and increases injury susceptibility through distorted movement patterns. From a performance perspective, relating to force production and attenuation, fatigue has been found to: cause an increased range of motion (i.e. reduced force over an excessively long time), which is important for force production and propulsion; cause a decrease range of motion (i.e. increased force being produced over an insufficient time), during force attenuation and landing manoeuvres (James et al., 2006; Thorlund et al., 2008). From a movement quality perspective relevant to joint risk, fatigue can cause altered sequential timing of muscle activation and joint movement. This causes the redistributing of force and impact attenuation strategies away from major muscle groups and efficient biomechanics (James et al., 2006). Moreover, specific biomechanical disruptions include reduced muscle stiffness, increased tibial shear force, reduced knee flexion angles on landing, and increased valgus and internally rotated angles (in female subjects especially) on landing (Augustsson et al., 2006; Chappell et al., 2005; McLean et al., 2007).

Stop jump and landing tasks have been found to account for more than 50% of knee injuries in sports like basketball and volleyball and to play an increasing role in snow sport injuries (Wikstrom, Powers, & Tillman, 2004). Anecdotally, this is reinforced by the awareness that it is the landing phase which is the most crucial in halfpipe because it shows completion of a trick as well as prepares the athlete for the next trick (O'Shea, 2004; Turnbull, Keogh, & Kilding, 2011). As identified from the snow sports injury research, the majority of injuries involve jumping and landing impact injury. Identifying appropriate timing and biomechanical patterns of landing force attenuation, as well as monitoring how these may change during fatigue, is therefore an important part of understanding the fatigue-injury relationship in halfpipe.

The acknowledgement of the importance of explosive power for jumping and landing efficiency by the coaching and sport science community has led to a number of robust measures of this training variable (Cronin & Hansen, 2005; Leard et al., 2007). Considering the number of landings and the importance they have for maintaining board speed in halfpipe, tests of explosive power appear pertinent to this sport (Frederick, 2006; O'Shea, 2004).

The most reliable field measure of neuromuscular capability (reflecting both explosive power and coordination) appears to be the countermovement jump (CMJ) (Chappell et al., 2005; Leard et al., 2007; Liebermann & Katz, 2003; Markovic, Dizdar, Jukio, & Cardinale, 2004). Markovic et al., (2004) investigated seven explosive jump tests including both vertical and horizontal based tests with semi-trained individuals (n=93), and found that while most measures they employed were internally valid and reliable, CMJ was the most reliable test for explosive power (r=0.98). CMJs are typically preferred due to simplicity. In addition, compared to other jumps the CMJ has been found to require fewer learning jumps prior to reliable data collection (Cronin & Hansen, 2005; Liebermann & Katz, 2003).

With respect to the halfpipe context, two other common vertical jump tests may be relevant as tests to assess performance potential during different phases of a run. For example, the speed and timing of the concentric phase of the squat jump (SJ) may be likened to coordinated movements of takeoff where an athlete produces a high impulse concentric movement to create rotation. In the halfpipe, the concentric movement consists of an anterior-lateral hip ñboostò (a high impulse rear leg and hip extension) and simultaneous lateral-vertical arm thrust (toward the front of the board) to assist horizontal velocity. However, the ability to produce high impulse concentric force is the critical element. (Note: Horizontal velocity relates to velocity in the sagittal or ñcartwheelò anatomical plane (King & Yeadon, 2004; Turnbull et al., 2011; Virmavirta, Kivekas, & Komi, 2001)). The SJ is also a simple and fast method to test muscular force and power without stretch shortening cycle (SSC) influence which provide a means of evaluating mechanical force capabilities. The control of centre of mass relative to gravity and the rapid turnaround from eccentric to concentric phases during the drop jump (DJ) and CMJ may be likened to landing where athletes must adjust board pressure (eccentric) and quickly pump (concentric) the transition to give them more speed (Cronin & Hansen, 2005; Strojnik & Komi, 1998; Tomazin, Dolenec, & Strojnik, 2008; Turnbull et al., 2011). The CMJ and DJ involve a greater input from the neural system than the SJ (Strojnik & Komi, 1998; Tomazin et al., 2008). Also of consideration is alteration in movement patterns with fatigue. The reactivity coefficient (defined through the contact time relative to drop height) identifies the bodyôs ability to transition from an eccentric to a concentric phase (Cronin & Hansen, 2005). This is important in non-optimal drop-ins and landings where the athlete must adjust board pressure and/or pump the transition to give them more speed. Similarly, the Eccentric Utilisation Ratio (EUR) identifies the difference between SSC and concentric-only movements by providing the difference between SJ and CMJ (McGuigan et al., 2006). Generally the CMJ will be greater than the SJ. McGuigan et al, (2006), found that the EUR differed between sport, gender and by training phase, but that in general SJ height was around 5-15% lower than the CMJ. At the end of a session if the gap between the CMJ and SJ has decreased, we can postulate that fatigue is the more neural faster SCC component. If the gap increases the fatigue may be more muscular.

Of the methods of neuromuscular investigation available there are several measurement devices commonly used including tendon transducers, strain gauges and load cells, force plates, linear position transducers (LPT) and contact mats (Cairns et al., 2005). Strain gauges, load cells, and tendon transducers are more suited to in-vitro laboratory investigation and are less portable forms of measurement. Force plates, LPTs and contact mats on the other hand provide a relatively easy method of immediately testing the variables (e.g. jump displacement, force, velocity and/or power), and current technology allows many of these devices to be transported to the field of play relatively easily (Augustsson et al., 2006; Drinkwater et al., 2007; Markovic et al., 2004). Until recently the contact mat appeared the most widely used due to both low cost and greatest ease of transport and setup (Markovic et al., 2004). However, the advent of cheaper and more portable/robust LPT has led to the increase in testing capabilities using these devices. LPT and force plates allow greater range of more directly and indirectly measured variables including rate of force development and other temporal variables. Triaxial force plates also provide information on horizontal forces on takeoff and landing.

While LPTôs have been found to be stable in laboratory environments there still needs to be validation studies in the field and with specific populations. Drinkwater (2007) compared a LPT to a criterion video analysis system for measuring power, reporting r values of Ó0.97 with CV of Ò3.0% for the LPT method. Cronin et al, (2004) compared force platforms to LPT, reporting mean force (MF), peak force (PF) and time to PF for SJ and CMJ, to be within the range of r=0.861-0.995. Furthermore they provide ICC and CV data identifying MF and PF were 0.908 and

0.982, and 2.1% and 3.2% for SJ and CMJ respectively. LPT are reportedly less reliable for temporal information such as time to peak force and rate of force development, most probably due to the differentiation required to infer these variables (Cronin et al., 2004; Harris, Cronin, Taylor, Boris, & Sheppard, 2010).

When considering jump-based tests, and indeed any test requiring maximal effort from people in fatigued states and/or during training and competition, we must be cautious of creating fatigue by doing the tests themselves. Idiosyncrasies of motivation, perceptions of effort, and the possibility that athletes may pace themselves during testing must be considered within testing methodologies involving fatigued individuals requiring maximal effort (Hopkins, Schabort, & Hawley, 2001).

b) Biochemical

While jump-based assessment may be simple and its validity clear, the body is a complex system. It is widely recognised the stimulus with which adaptation occurs in an athlete comes from the internal TL ï the compounded stress the athlete is subjected to (Impellizzeri et al., 2004). This internal load identifies how the athlete copes with the prescribed external TL within the context of their daily life and is relative to how they perceive and manage their immediate environment (Impellizzeri et al., 2004; Moyle & Terry, 2005). Coaches therefore need to consider not simply the standard volume and intensity prescriptions but specifically how their individual athletes are internalising the load.

Increased levels of acute psychological stress are known to alter homeostasis as much as a hard training session (Chatterton, Vogelsong, & Lu, 1997; Kivlighan, Granger, & Booth, 2005). For example, Chatterton and others (1997), found that prior to a significant stress event (first-time skydiving) the sympathetic nervous system (SNS) was excited, resulting in elevations in catecholamine, cortisol, amylase, prolactin, and growth hormones levels, each of which act to increase heart rate, blood pressure and blood glucose concentrations (Chatterton et al., 1997; Kivlighan et al., 2005). Kivlighan and others (2005), provide an extensive review of the impact of gender, experience and ability on stress hormone (cortisol and testosterone) response. They found that participants who were not experienced in the event or who were in competition exhibited higher levels of cortisol prior to the event than experienced participants, concluding that during these circumstances the individualsô systems was working hard to maintain homeostasis and SNS activity (Kivlighan et al., 2005).

SNS hormone response is an indication the body is/has been under stress and is trying to heal itself (McArdle, Katch, & Katch, 1991). Confounding this however, Rietjens et. al, (2005) found that during protocols to induce overtraining, there is a reduced responsiveness to stress indicators, reducing the production of SNS hormones such as cortisol and testosterone as well as depressing HR. Considering the purpose of these hormones is for healing and recovery their monitoring may provide an effective tool as to the load an athlete is under at a given time (Chatterton et al., 1997).

Several biochemical and hormonal methods are available for monitoring training and stress in athletes. Although much of the research has used endurance athletes some markers can be used to examine general bodily stress. The more commonly reported methods of assessing biochemical changes as a result of fatigue are identified in

Table 2.

Table 2. Authors and their research into biochemical markers relevant to fatigue.

Author	Variable Used	Reported Relevance to Fatigue
Morton (1997) Petibois et al, (2003)	Creatine phosphoskinase, lactate dehydrogenase and aspartate amino transferase	Markers of cellular leakage, and muscle fibre degradation
Petibois et al, (2003)	Carbohydrate, protein and lipid metabolism rates and sequence	Markers of metabolism alterations between rest and exercise
Gabriel et al, (1998)	Immune cell count and makeup in peripheral blood	Alterations in immune and hormone response as a result of training stress
Chatterton et al, (1997) Hellhammer et al, (2009) Kivlighan et al, (2005) Filaire et al, (2001)	Cortisol	Found to be a reliable index of stress as increased sympathetic nervous system prepares for the impending activity
Kaufman et al, (2009) Kivlighan et al, (2005) Lehmann et al, (1993)	Testosterone	Used as a measure of competitiveness, dominance, and aggression ï behaviours based on increased sympathetic nervous system activation, alertness and readiness. Increases in cortisol and decreases in testosterone are typical responses to high intensity physical training

Blood has previously been the preferred collection medium for most compounds used in biochemical testing as it often the most direct and accurate medium where these compounds are found (Hellhammer et al., 2009; Kaufman & Lamster, 2009). Saliva testing however can be done easily, noninvasively and without the need for specialised training or equipment, causing less stress and disruption than blood or urine sampling (Hellhammer et al., 2009; Kaufman & Lamster, 2009). While analysis is still restricted to the laboratory, the process of analysis is relatively straight forward and often relatively fast per sample. So long as salivary gland function is normal and that the salivary marker used has a strong correlation to serum concentrations (which is the case for cortisol and testosterone) (Terry & Lane, 2003; Terry, Lane, Lane, & Keohane, 1999), saliva can be a very reliable and accurate tool for measuring the amount of stress the body is having to tolerate (Kaufman & Lamster, 2009).

c) Psychological

Following hormone disturbance, mood disturbances have been negatively related to increases in TL and closeness to competition (Filaire et al., 2001). Negative mood states and disturbed mood patterns have also been shown to increase athletesô RPE at given workloads, reduce motivation and generally impair training and competition performance (Marcora et al., 2009; Morgan et al., 1987). An athleteôs psychological state and trait can alter the inclusion decisions they make (i.e. ñyes I will participateò or ñno I wonôtò), the intensity they work at (i.e. ñI want to take it easy todayò), and less noticeably can affect how the body deals with the same external workload (e.g. increased RPE and/or heart rate relative to previous sessions, biochemical changes etc) (Cohen et al., 1983; Impellizzeri et al., 2004). Longitudinal studies have identified negative mood states as a signal, if not a precursor to overtraining symptoms (Filaire et al., 2001; Morgan et al., 1987). More specifically, some authors have found that mood state exploration can differentiate non-athletes from athletes. The Iceberg Principle for example (as described by Morgan and others (1987)) holds that athletes are above normal on the positive Vigour subscale (1 standard deviation) and below average (0.5 standard deviation) on the negative subscales of Anger, Confusion, Depression, Fatigue, Tension.

Moyle and Terry, (2005) suggest the use of psychological mood scale tool for óred-flaggingô injury susceptible athletes. Of the psychological tools used for investigating mood and fatigue, most focus on evaluating negative constructs, because while positive mood states may be associated with high quality physical training, the decline in mood and the presence of apathy are often reported in fatigued athletes. The Profile of Mood States (POMS) appears to be the most widely used for investigating mood. However there has been criticism over its use within athlete and adolescent populations (Terry & Lane, 2003; Terry et al., 1999). The 64 item POMS was originally constructed and validated using adults and psychiatric outpatients, and is lengthy and literarily complex (Filaire et al., 2001; Rietjens et al., 2005; Terry & Lane, 2003; Terry et al., 1999). Another is the Perceived Stress Scale (PSS), which asks individuals the degree to which situations in their life are appraised as stressful. The PSS is a 14 item questionnaire directed at identifying unpredictable, uncontrollable, and overloading aspects of life (Cohen et al., 1983; Moyle & Terry, 2005). While the PSS may be used to assess stress outcomes and provide information as to an individualôs ability to cope with situations in the future, it may be of less use as a regular measure of the more stable mood construct important in injury prevention (Cohen et al., 1983; Moyle & Terry, 2005).

The Brunel Mood States (BRUMS) questionnaire (also known as the POMS-A, where A stands for Adolescent) provides a more valid and feasible alternative to the lengthy POMS. The BRUMS is designed towards athlete and adolescent culture and language, and has been validated using both adult, athlete and adolescent athlete populations (Terry & Lane, 2003; Terry et al., 1999). The BRUMS is a 24 item self-report measure, involving the six areas of mood outlined in the Iceberg model, with four questions relating to each area. Where the POMS and PSS use response timeframes of one month to a year, the usefulness of the BRUMS to sporting contexts is that the standard response time is immediate with the general response timeframe of ñhow you feel right nowò (Moyle & Terry, 2005; Terry & Lane, 2003). Thus it can be used to measure the acute response to an event ï whether this is a training session or a stressful argument. Excessive use of the BRUMS may reduce the power of measurement, however relying on only one or two acute measures to identify a period is also questionable.

Using any form of subjective measure which requires an athlete to answer questions is dependent on the subjectôs understanding of the questions and wording. Furthermore, any investigation into mood states needs to consider the response set and the number of interventions relative to the time period to ensure questionnaires are considered carefully (Morgan et al., 1987). Practitioners should therefore be cautious to ensure questionnaires address the sporting context (i.e. question relative to the ósessionô not just the day), culture (i.e. utilise culture specific language), the age of the subject (i.e. relative to education) and that their length and language are adjusted according to the timing of the subsequent tests (Terry et al., 1999).

Conclusions, And Practical Recommendations

Much of the fatigue and TL literature has been based on steady state or cyclic activity and involves single sport science disciplines rather than a multifactorial approach. Cyclic sports enable a stable and quantifiable fatigue protocol where, with laboratory based testing, the knowledge gained from a single testing session can be highly valid and reliable. The incorporation of skill-based, extreme environment, high-risk sports, which include significant power production and eccentric muscle activity, requires further research before coaches and scientists may make specific training and performance decisions. Specifically, the start-stop nature of halfpipe means that monitoring load and identifying a stable fatigue profile is difficult. Identifying and sustaining a structured fatigue protocol from which sports scientists may develop and validate reliable tests, remains a valuable future endeavour. Such a protocol needs to account for environmental factors such as halfpipe condition, weather and the idiosyncrasies of fear and motivation for training in this risk-based sport.

Separating fatigue into neuromuscular, biochemical and psychological expressions provides a good model within which to study fatigue and its markers. With the complexity of the halfpipe training environment, it is unlikely any one tool will provide effective information to coaches and sport scientists. Therefore in order to fully understand such an environment, fatigue studies should include a multifactorial approach, taken consistently over several training sessions. Monitoring individuals may allow coaches to build a picture of how that individual is reacting to training stimuli and may be more advantageous than group trends in such a complex environment.

Several considerations should be made when launching a fatigue monitoring project. Due to a high dependency on athlete motivation and achieving an effective psychological state for working on new tricks, subjective rating scales may provide valid information as to what to do within a session on a day to day basis. The use of objective measures however is still invaluable to understand the avenues of fatigue, for validating subjective measures, and for long term monitoring and quantification of relationships between TL, performance and injury. Such knowledge will allow coaches to plan training sessions and react to athlete wellbeing more efficiently and will assist scientists in more accurate prescription of dry land training and of recovery protocols.

In summary, the direction of future research should focus both on the load demands of halfpipe as well as the fatigue these athletes experience during training and competition. Without empirical data on the load of training and the resultant fatigue, sport scientists are unable to effectively suggest changes to either coaching practice or recovery methodologies.

CHAPTER 3: EXPERIMENTAL RESEARCH

THE FEASIBILITY OF MONITORING TRAINING LOAD AND FATIGUE MARKERS IN SNOWBOARD & FREESKI HALFPIPE

RUNNING HEAD: Monitoring fatigue in halfpipe athletes

Abstract

PURPOSE: Little published research exists surrounding training load and fatigue accumulated during snowboard and freeski halfpipe training. The aim of this investigation was to examine the feasibility of collecting objective and subjective data for inferring within- and between-day trends in load and fatigue during halfpipe training. METHODS: Ten male and 14 female elite halfpipe athletes, (21.8±3.3 y, and 23.4±4.6 y respectively) were observed during a 2 week on-snow training camp. Subjectsô pre-session countermovement jump (CMJ) and level of perceived fatigue (LPF) were recorded as were post-session CMJ and rating of perceived exertion (RPE). A linear position transducer (LPT) was used to measure mean power (MP), peak velocity (PV), and jump height (JH) from the CMJ. Reliability was established using coefficient of variation and a repeated-measures generalised estimating equations (GEE) model used to examine relationships between variables within-day and between-day over the course of the camp. RESULTS: Significant relationships were found between post-session RPE and load, and next-day MP and PV in that, as the subjective variable increased the next dayôs objective variable reduced by varying factors. Pre-session LPF increased as training days progressed. CONCLUSIONS: No significant relationships were observed within-days, and it is therefore suggested that on-going between-day monitoring, incorporating both subjective and objective methods be used. It was concluded that monitoring subjective self-reports of intensity and fatigue in conjunction with objective measures used to infer these phenomenon can be a useful tool for coaches and scientists to prescribe appropriate training loads and monitor fatigue.

Key Words: Snowboard, Freeski, Halfpipe, Fatigue, Load

Introduction

Snowboard and freeski halfpipe are skill-based sports performed in high-risk alpine environments, where training opportunities are highly dependent on snow, weather and facility access. In order to maximise training, coaches must balance training opportunity and intended session intensity with their athleteôs energy, motivation and health. Sports scientists must in turn be able to adapt their athletesô training on a daily basis in relation to variations in fatigue levels if they wish to maximise the potential for skill development and minimise the risk of fatigue-related injury.

The limited performance-based halfpipe research existing is characterised by limited athlete numbers and/or manipulated training environments. For example, Kippôs (1998) field study into how hard halfpipe athletes may be working on-snow involved monitoring the heart rate and lactate of only three elite halfpipe athletes on a single day. Kipp (1998) reported average blood lactate of 2.9mmol^{-1} and percentage of maximum heart rate (HR) to be around 92% at the end of a halfpipe run. Arruza et al. (2005) used a manipulated training environment to examine the relationship between self-reports of fatigue and intensity, and HR of five elite halfpipe athletes. They reported that training demand was significantly related to HR (r=0.74), fatigue (r=0.84), and intensity (r=0.87) respectively and that fatigue and intensity were highly related (r=0.96).

Contemporary definitions of fatigue, considered within this investigation, identify fatigue as a feeling of tiredness and a lack of focus as a result of physical and/or mental work, presenting in an inability to perform a session at the required level after intra or intersession recovery (Knicker et al., 2011; Morton, 1997; Strojnik & Komi, 1998). In risk-based sports coaches need to ensure the onset of fatigue is identified before an exhaustion/failure response occurs. Research suggests that if markers of fatigue continue to increase, either performance will decrease (i.e. amplitude, trick execution) and/or an injury will occur (i.e. impact or overuse) (Knicker et al., 2011; Strojnik & Komi, 1998).

Borresen and Lambert (2008), reported that athletes are inherently aware of the physiological stress they are under during exercise. Self-report scales are regularly reported to be the easiest, cheapest and most robust form of training load (TL) calculation (Borresen & Lambert, 2008; Foster et al., 2001; Gabbett & Domrow, 2007; Impellizzeri et al., 2004). Concurrently, considering the number of landings and the importance they have for maintaining board speed, objective tests of explosive power are also pertinent to halfpipe (Frederick, 2006; O'Shea, 2004). Tests of explosive power have regularly been used to infer acute fatigue responses in a range of fatiguing activities (Markovic et al., 2004; Power, Behm, Cahill, Carroll, & Young, 2004; Thorlund et al., 2008).

While these measures do not specify which mechanism caused the fatigue (e.g. the environmental conditions, the eccentric impact of numerous landing, the psychological pressure to execute risky tricks), they do provide established protocols and values from which to observe change, and from which we may infer a fatigue effect.

Considering the newness of these sports to scientific investigation it seems prudent that initial investigations focus on observational methodologies, limiting the interruption to athlete and coach training environment. The aim of this investigation was to examine the feasibility of collecting objective and subjective data for use in inferring within- and between-day trends in load and fatigue in halfpipe training. Further, considering the limited depth of research, a secondary aim of this investigation was to report and discuss any relationships found and provide guidance to future investigation. It was hypothesised that decreased performance in objective markers would be associated with increases in subjective markers following a training session. Additionally it was hypothesised that the previous dayộs training would impact on the next morningộs fatigue markers.

Methods

a) Subjects

Twenty-four subjects, 10 male (21.8 ±3.3 y) and 14 female (23.4 ±4.6 y), participated over the course of a two week camp. The group comprised of international halfpipe athletes targeting the 2014 Olympic Winter Games, attending a private training camp in New Zealand. All subjects were aligned to an elite National team and under the guidance of a coach. Ethics approval was obtained from the Auckland University of Technology Ethics Committee.

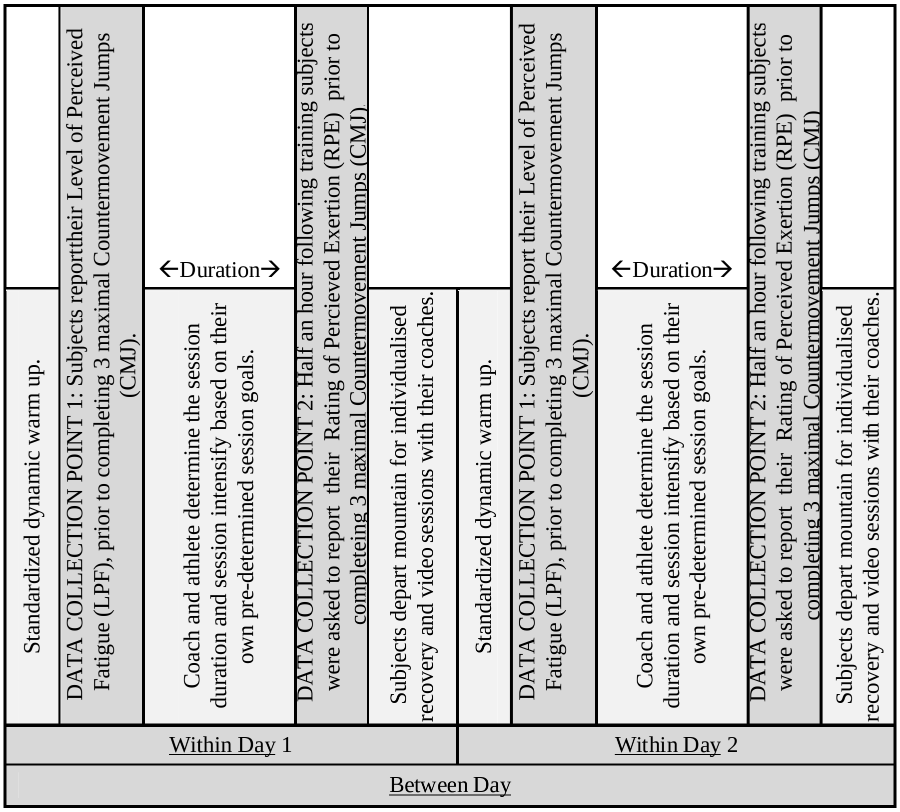
Informed consent was obtained outlining subjectsô ability and willingness to take part in the investigation, their status as injury free, and their ability to withdraw at any time. Subjects were instructed to provide maximum effort and educated on how the investigation and its outcomes were relevant to them as competitive athletes. Altitude of the camp was 1600m. All athletes were accustomed to training at altitude and had been riding at the resort the week leading up to the training camp. Subjects were excluded if unable to consistently train and/or if injury prevented them regularly and safely participating in the camp. A physiotherapist was present during all on-snow training to ensure injury status was monitored. Days 7 and 8 were bad weather days where no one trained. Individual routine meant that not all subjects tested both pre and post each day. Statistical methods, outlined below, were used to account for this.

b) Design

A within-subject, repeated-measure, observational design was used. The investigation design was considerate of not affecting the training structure of the camp. As is standard with halfpipe training, subjects had their own individualised goals and session plan and ceased training when they and their coach felt it appropriate. Typically in practice males and females train together. Therefore, unless initial data analysis identifies significantly different trends for males and females, their data were pooled.

c) Methodology

Each day during the on-snow camp a standardised warm-up was performed prior to pre-session testing, and included five minutes ergometer cycling followed by dynamic stretching and a series of warm up jumps. Subjects then underwent a pre-session jump assessment and reported their level of perceived fatigue (LPF) (Figure 4). Half an hour following their on-snow session (allowing them time to return to the base lodge for testing), subjects repeated their jump assessment and reported their rating of perceived exertion (RPE) (Figure 5). Testing occurred each day of riding in order for within and between day measures to be made over consecutive days (Figure 3).


Standardized dynamic warm up.

DATA COLLECTION POINT 1: Subjects reporttheir Level of Perceived Fatigue (LPF), prior to completing 3 maximal Countermovement Jumps (CMJ).

←Duration→

Coach and athlete determine the session duration and session intensify based on their own pre-determined session goals.

DATA COLLECTION POINT 2: Half an hour following training subjects were asked to report their Rating of Percieved Exertion (RPE) prior to completeing 3 maximal Countermovement Jumps (CMJ)

Subjects depart mountain for individualised recovery and video sessions with their coaches.

Standardized dynamic warm up.

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Within Day 1

Within Day 2

Between Day

Figure 3. Example of two days of testing, indicating the time course of testing providing Within Day and Between day data periods

Duration was identified as the time between pre-session and post-session testing. Load was calculated by multiplying RPE by duration (Borresen & Lambert, 2008). LPF and RPE scales were posted on walls around the testing room to ensure subjects were familiar with the terminology and scaling (2008). Several training sessions were used for familiarisation of all subjects in the week preceding the camp. All testing was undertaken indoors in a warm room 500 metres away from the bottom of the pipe. Subjects wore their thermal underwear with snowboard boots off during jump testing sessions.

"WHAT IS YOUR CURRENT LEVEL OF FATIGUE/EXHAUSTION?"

0 – 10%	*(No Fatigue)*
10 – 20%	
20 – 30%	
30 – 40%	
40 – 50%	
50 – 60%	
60 – 70%	
70 – 80%	
80 – 90%	
90 – 100%	*(Completely exhausted)*

Figure 4. Level of Perceived Fatigue (LPF) scale as reported by Arruza et al, (2005)

"HOW HARD WAS YOUR SESSION?"

0	Rest
1	Really easy (Very,very easy)
2	Easy
3	Moderate
4	Sort of hard (somewhat hard)
5	Hard
6	
7	Really hard
8	
9	Really, really hard
10	Just like my hardest race ever (Maximal)

Figure 5. Rating of Perceived Exertion (RPE) scale as reported by Borresen and Lambert (2008). (In brackets are the terms used by Foster (2001)).

Jump assessment comprised of three maximal bodyweight countermovement jumps, with one minute between trials. The average of three jumps were taken for analysis (Feltner, Bishop, & Perez, 2004; Markovic et al., 2004). Hands were placed on hips during all jumps, with the verbal cue given as *"jump as high as possible"* (Crewther, Cronin, & Keogh, 2005). Subjects were instructed to leave the floor and land with ankles and knees fully extended (but not locked) to allow accurate measurement (Feltner et al., 2004; Power et al., 2004).

Mean power (MP), peak velocity (PV), and jump height (JH) were measured using the GymAware linear position transducer (LPT) (Kinetic Performance Technology, Canberra, Australia). The GymAware system is a displacement-time data recorder using a signal-driven sampling method with a resolution of 0.035 milliseconds and a sample rate of 50 Hz. The GymAware tether was attached behind the subject via waist harness. Body weight was chosen for the investigation due to restrictions of the testing environment on the mountain. Argus and colleagues (2011), investigated the efficacy of body weight, assisted and resisted jumps using GymAware. They reported interclass correlations for force, velocity and power outputs to be within the ranges of r=0.985-0.990 for bodyweight CMJ.

d) Statistical Analysis

SAS software (Version 9.2) was used to analyse all data with significance set at Ǔ level 0.05. Means and standard deviations are presented throughout to represent centrality and spread of data. Data were checked for normal distribution and parametric tests employed. Descriptive statistics summarising the subject characteristics including age, gender, sample size, were obtained. Reliability was calculated using coefficient of variation (CV).

Data were analysed using a repeated measures generalised estimating equations (GEE) model. The AR1 structure (autoregressive model based on one time unit before present) was used, identifying that the measurement of a variable is associated with the measurement of the previous day, and additionally meaning that the relationships with previous days' measurements reduces with the increased number of days. Over other repeated measures methods, the GEE model was used to account for missing data since it infers values for missing data from those values surrounding it. This model adjusted for the design effects of subject and day, as well as the fact that there was some data missing for some individuals on some days (Hanley, Negassa, Edwardes, & Forrester, 2003).

Results of the GEE are presented as a sensitivity coefficient (percentage), describing how changes in one variable (previous dayôs training) impact another (todayôs capability). Negative coefficients identify that as one variable increases, the other decreases.

Results

Males and females train together at the same time, therefore, where no significant gender response was observed, gender was pooled. Therefore, while Table 3 shows the results separated by gender cohort for both subjective and objective measures, gender was pooled for across camp trends in single variables and reliability, but separated for the within- and between-day analyses.

Pooled results across the testing period for male and females found CVôs for MP (5.62±3.30%), PV (4.02±2.23%) and JH (3.94±2.52%) to be acceptable. Subjects were found to exhibit greater jump performances post- than pre-session. Males and females showed similar pre-post changes in MP (5.5 and 5.6% respectively). Males showed greater percentage increases in PV (4.2 and 2.4% respectively) but smaller percentage increases in JH compared to females (2.0 vs 3.1%) from pre- to post-session. While pre- to post-session changes can be seen across the day for both genders, all percent change measures showed variability.

Table 3. Descriptive data for males and females.

			Male			Female		
			Mean		Standard Deviation	Mean		Standard Deviation
Subjective	Pre Session	Level of Perceived Fatigue	23.7	±	14.1	15.3	±	12.3
	Post Session	Rating of Perceived Exertion	4.3	±	1.9	4.1	±	1.9
		Duration (hours)	3.4	±	1.3	3.4	±	1.1
		Load (Duration x Rating of Perceived Exertion)ơ	15.3	±	9.1	15.0	±	9.0
Objective	Pre Session	Mean Power (W)	1668	±	491	1081	±	191
		Peak Velocity (m/s)	2.59	±	0.36	2.16	±	0.22
		Jump Height (cm)	45.4	±	8.9	34.9	±	5.300
	Post Session	Mean Power (W)	1764	±	521	1136	±	160
		Peak Velocity (m/s)	2.69	±	0.36	2.21	±	0.20
		Jump Height (cm)	45.5	±	9.8	36.1	±	5.6
	Percent Change from Pre to Post	Mean Power (%)	5.5	±	9.4	5.6	±	12.6
		Peak Velocity (%)	4.2	±	6.6	2.4	±	7.3
		Jump Height (%)	2.0	±	16.4	3.1	±	13.3

ơIt is important to note that, considering load is the product of hours trained and intensity trained (1-10), then a unit change in load may occur through an increase in the duration of training, and/or an increase in the intensity of training. For example, training for 3 hours at an RPE of 4 gives a Load of 12, while training for 3.5 hours at the same intensity yields a Load value of 14.

When analysed independently across the camp, there was no significant effect of day across the camp for the objective variables, MP, PV, and JH as presented in Figure 6. The subjective LPF (Figure 6A) however, exhibited a significant (pÒ0.001) increase as the camp progressed.

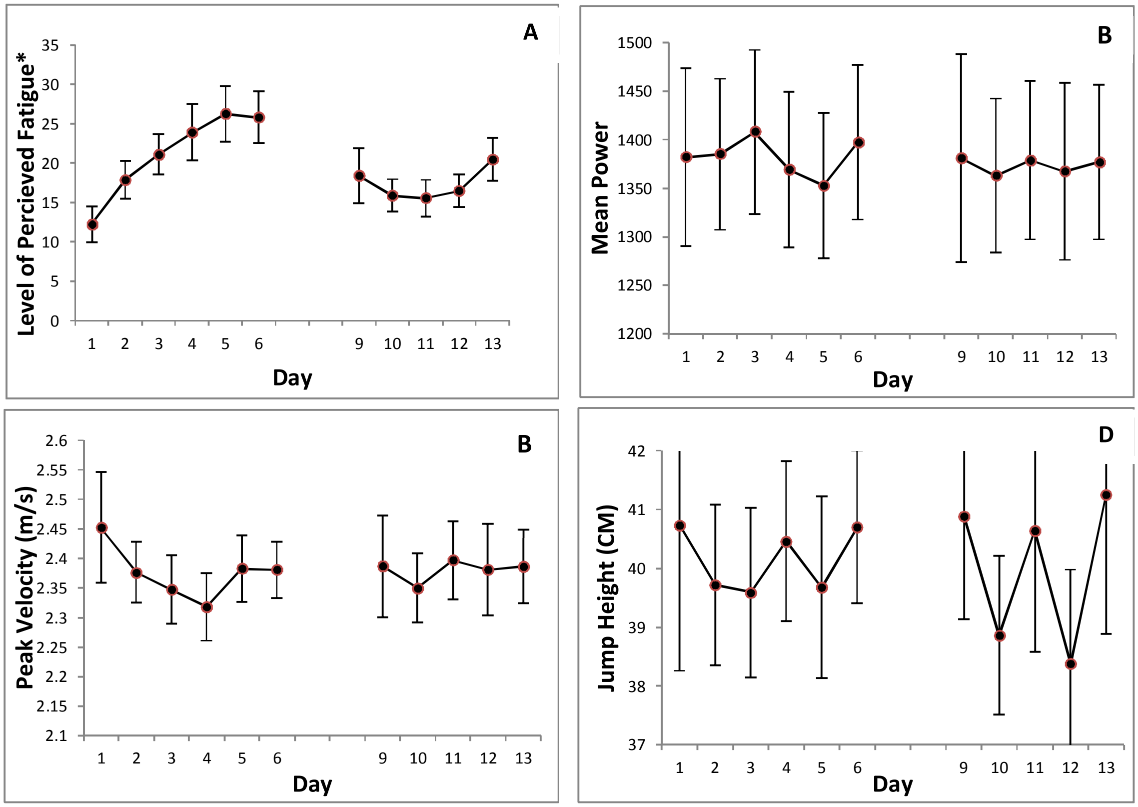

Figure 6. Results of GEE estimated marginal means analysis of pre session subjective and objective measures combining gender across the course of the camp. Note days 7 and 8 were non-training weather days. (*Level of Perceived Fatigue (LPF) is significant at p <0.001).

There was no significant relationship found between subjective variables (load and RPE) and objective variables (post-session and change-in MP, PV, JH) following a dayôs training. High variability was found in the within-day results.

Several significant results were found in between-day observations (Table 4). For males, for every unit change in TL, the next dayôs MP and PV were negatively affected by a factor of 4.68%, (p=0.03), and 0.01% (p=0.00) respectively. In absolute change terms, based on the average pre-session results identified in Table 4,

a unit change in TL therefore equates to 78W change in MP and a 0.003m/s change in PV. For every unit change in the previous days RPE, MP and PV were negatively affected by a factor of 19.83% (p=0.05) (absolute change of 331W) and 0.04% (p=0.02) (absolute change of 0.01m/s) respectively. For females, for every unit of previous dayôs change in PV, LPF was positively affected by a factor of 36.60% (p=0.04) (absolute change of 5.6 units). For females a unit change in the previous days JH affected the next dayôs JH by a factor of 0.08% (p=0.02) (absolute change of 0.03cm).

Table 4. Between-day post-session to pre-session analysis of GEE parameter estimates & score statistics for type 3 GEE analysis.

			Male			Female	
	Previous Dayôs:	Coefficient[ǂ(]	Standard Deviation	*p* Value	Coefficient[ǂ(]	Standard Deviation	*p* Value
Level of Perceived Fatigue	Rate of Perceived Exertion	0.33	2.18	0.77	0.38	1.52	0.65
	Duration	1.35	5.11	0.64	-0.24	2.79	0.87
	Load	0.02	0.49	0.93	0.05	0.36	0.78
	Change in Mean Power	-5.90	23.85	0.63	-12.50	12.13	0.14
	Change in Peak Velocity	-0.60	35.85	0.97	-36.30*	20.41	0.04
	Change in Jump Height	5.18	7.87	0.36	1.89	13.78	0.79
Pre Session Mean Power	Rate of Perceived Exertion	-19.83*	12.75	0.05	3.25	10.06	0.55
	Duration	-3.95	51.95	0.89	26.95	30.69	0.10
	Load	-4.68*	2.26	0.03	1.80	1.97	0.13
	Change in Mean Power	264.77	363.30	0.17	98.00	186.47	0.40
	Change in Peak Velocity	348.73	518.31	0.26	145.03	391.12	0.54
	Change in Jump Height	-11.06	120.54	0.86	7.01	182.52	0.94
Pre Session Peak Velocity	Rate of Perceived Exertion	-0.04*	0.02	0.02	0.00	0.01	0.87
	Duration	0.00	0.08	0.99	-0.01	0.05	0.78
	Load	-0.01*	0.00	0.02	0.00	0.00	1.00
	Change in Mean Power	0.16	0.22	0.20	-0.13	0.42	0.55
	Change in Peak Velocity	0.31	0.44	0.32	0.00	0.65	0.99
	Change in Jump Height	0.03	0.21	0.78	0.02	0.19	0.81
Pre Session Jump Height	Rate of Perceived Exertion	0.01	0.01	0.14	0.00	0.00	0.73
	Duration	0.01	0.02	0.55	0.00	0.01	0.48
	Load	0.00	0.00	0.22	0.00	0.00	0.12
	Change in Mean Power	0.04	0.08	0.29	0.04	0.07	0.38
	Change in Peak Velocity	-0.01	0.17	0.89	0.05	0.11	0.42
	Change in Jump Height	0.06	0.14	0.33	0.08*	0.03	0.02

* Indicates significant values (p= 0.05). [Ø]Coefficients indicate the percentage change relationship the previous day has with the next dayôs pre-session variable.

Discussion

Monitoring the effect of a training session on training related variables helps scientists understand the acute impact of training and may direct skill development and recovery prescription (Drinkwater et al., 2007; Gabbett & Domrow, 2007; Morton, 1997). If halfpipe coaches and athletes are more aware of TL and fatigue during normal training, they may make more informed decisions regarding individualised session planning, when to cease session or when to persevere, and how long athletes need to recover between training sessions.

This investigation examined the feasibility of collecting objective and subjective data for use in inferring trends in load and fatigue in halfpipe training. If objective markers were found to be directly associated with subjective markers of fatigue following a training session then coaches could reliably implement these simple self-report measures to adjust training and recovery practice on a daily basis. However we failed to find significant within-day relationships, from which such scales may be easily validated. This does not necessarily indicate that there was no fatigue, simply that our measures may not have been sensitive enough for within-day monitoring.

When observing between-day variables, we found several significant relationships indicating that pre-session variables were sensitive to the previous dayȯs training. Cautious that our measures may only be used to infer load and fatigue and do not specify the mechanism of fatigue, several relationships are of interest. When grouped by gender, males showed several relationships inferring that their morning jump capabilities may have been impacted on by how hard they perceived they had worked the previous day. Specifically, for males, the next dayȯs MP and PV scores were negatively impacted on by TL by a value of 4.68% (p =0.03) and 0.01% (p=0.00) respectively and by RPE, by values of 19.83% (p=0.05) and 0.04%

(p=0.02) respectively. Females on the other hand, showed a significant relationship between the previous days change in PV and next dayộs LPF whereby LPF was positively affected by a value of 36.60 (p=0.04). These results indicate that females may be impacted on by previous-day objective physical performance rather than how hard they thought they worked.

When considering the feasibility of monitoring our subjective and objective markers and using them to infer a fatigue response in this cohort, several reflections and methodological considerations are important. The lack of evident within-day fatigue markers was unexpected considering the general acceptance that explosive power is a valid and reliable marker of fatigue within the coaching and sport science community (Crewther et al., 2005; Leard et al., 2007; Power et al., 2004). Although CMJ has been reported to be the most reliable field measure of neuromuscular capability, there may be other jumps or dependant variables more relevant to the mechanics of halfpipe (Chappell et al., 2005; Cormack et al., 2008; Feltner et al., 2004). For example reactivity measures such as the Eccentric Utilisation Ratio (EUR) (McGuigan et al., 2006) which considers the difference between squat jump and CMJ, may be more effective in identifying the type of fatigue occurring during halfpipe training. McGuigan et al. (2006), investigating EUR changes by sport and from off-season to pre-season of several team field sports suggested EUR as a means of tracking changes in training status.

The increase between pre and post-session jump scores was unexpected. We found increased jump capabilities in all variables, (MP, PV, JH) in the afternoon (up to 5.6% increase) which was surprising given the fact that athletes were riding for over 3 hours, mostly attempting new tricks, had access to a lift meaning they got more runs with less hiking. It was assumed that these factors would have impacted the neurological system greatly through increased eccentric load of more take-off and landing manoeuvres. While increased objective scores at the end of training may indicate an acute potentiation effect, one would have predicted the pre-session scores to decline over the course of the camp ï this was not the case. This effect may have been due to methodological issues with respect to motivational aspects of this cohort and/or diurnal variations.

Testing maximally in performance settings requires consideration of fatigue, motivation and technique. Although we identified some alterations in jump performance we did not monitor movement patterns objectively, especially those associated with knee or hip biomechanics. Identifying how halfpipe training affects kinematics could be a useful future research direction, especially given recent research into joint injury rates amongst snow sports athletes (see Flørenes, Nordsletten, Heir and Bahr (2012) for example).

Recent studies identify that due to variations in body temperature the time of day of testing needs consideration when testing explosive power. Increases of 2ï 6% in afternoon CMJ have been reported, which is consistent with the increased scores identified in this investigation (Taylor, Cronin, Gill, Chapman, & Sheppard, 2011). Longer warm ups when testing (or performing) in the morning have been suggested (Taylor et al., 2011). While the warm-up used during the current investigation was standardised and well adhered to, it was not as long as those used in clinical settings (typically 10 to 20 minutes) (Cronin et al., 2004; Markovic et al., 2004; Taylor et al., 2011). We shortened the warm up to minimise the impact on the athletesô training session. While time of day may affect body temperature through diurnal variations, logistical issues of warm-up and interruptions to the normal sport settings were a consideration in the design of the current study (Sporer, Cote, & Sleivert, 2012).

There were no significantly different trends for male or female when examining subjective or objective measures in isolation, and as such, genders were pooled to examine intra-variable trends across the camp. As Figure 3B, C, and D identify, MP, PV and JH exhibited no apparent significant trends. The significant trend that LPF (Figure 3A) followed was the expected trend of all variables ï that as training continued, markers of fatigue would increase.

Despite their use and reported reliability in the literature, the lack of participant familiarity with the LPF and RPE scales may have contributed to the variability seen in our results (mean LPF: male 23.7±14.1, female 15.3±12.3, and mean Load: male 15.3±9.1, female 15.0±9.0). Such variability may have contributed to the lack of any significant patterns within-days. Utilising more specific wording and/or using another scale altogether for the pre-session may be useful. Considering anecdotal reports of the importance of psychological factors in such a risk based sport, a scale of motivation or psychological stress may be pertinent to halfpipe, although this would need further research (Chatterton et al., 1997). A scale of motivation may also provide context to pre-session measures, and more specific information to the coach as to how the session should progress or what they should do to motivate the athlete to take the required risks. Similarly, a scale of effectiveness following a training session could also add context to any subjective and objective data. If an athlete is feeling tired and/or is jumping poorly but this is not associated with reduced effectiveness on snow (i.e. they are still achieving their goals), then arguably the recording of these fatigue and load markers may not be valid. Specific scales and their wording requires further research for this cohort.

LPF was recorded at the start of the session, while RPE was recorded following the session. Although Arruza et al., (2005) found LPF to be highly correlated with RPE, (r=0.96), and noted that these two scales do represent conceptually and temporally different variables, the use of separate scale systems (LPF was 0-100% and RPE 1-10), could have confused our subjects despite consistent reminding and visual scales being provided. For example, during familiarisation there was some confusion over LPF. Some subjects identified LPF as the soreness of specific muscle groups rather than overall fatigue, while others considered that since it was morning, this was their baseline for the day and consequently gave a rating of no fatigue.

Another plausible explanation why subjective or objective variables were not found to be related or sensitive to a dayĝs training, is that athletes may not have been working hard enough for our variables to pick up acute changes. From observation during training, athletes appear to spend a large amount of time on lifts, in queues, and/or talking with coaches, with proportionately less time spent actually riding the halfpipe. Considering a halfpipe run only takes 30s and lift riding, queuing, and coaching interactions could be anywhere from 5-20 min this means only 1.5-6 min per hour (3-10% of the hour) may actually be spent riding. Any actual feeling of exertion may be lost in the noise of this other low intensity activity. Specifically, Borresen and Lambert (2008) and Foster (1998) identified that both HR and RPE were poor indicators of fatigue at very high and very low activity levels. It could be postulated therefore that the concept of intensity may be less pertinent than a consideration of fatigue or tiredness from the day spent concentrating, being in the sun, altitude and/or cold. This may be backed up by the relatively low RPEs reported during this investigation (4.3±1.9, and 4.1±1.9 for males and females respectively) compared to Aruzza et al. (2005) whose subjects all reported maximal values achieved from hiking.

Practical Applications

Although, presentation of fatigue from halfpipe training may take several days, the results of single or a few testing sessions should not be dismissed. Specifically the acute increases in post session jump scores (relative to pre-session) may not be indicative of no fatigue ï monitoring over consecutive days will be required to identify fatigue using this tool.

It is recommended that coaches use LPF self-report measure to track their athleteôs fatigue as well as to guide decisions regarding session content and length. Following training, monitoring athletesô RPE still appears a useful tool. Considering these two scales measure distinctly different variables, using both these scales along with a pre-session motivation scale and/or a post-session effectiveness scale, could be a powerful planning tool for coaches and a monitoring tool for scientists.

Objective measurements requiring maximal effort, attention to technique and minimal time may be most effective when incorporated post-session due to reduced training session interruption. While this investigation failed to find any within-day relationships between the objective and subjective measures we used, validating self-report measures and quantifying load of a training session remains a valuable endeavour.

Conclusion

It is reasonable to think that halfpipe athletes would experience training related fatigue. That we did not observe such a downward within-session fatigue trend is perhaps owing to one or a combination of the following: athletes were not training hard enough to develop sufficient fatigue; that they were recovering well, adjusting their day to day TL to accommodate fatigue; that there is indeed fatigue but our measures were not sensitive to it; that other forms of fatigue are present; and/or that halfpipe training actually potentiates the neuromuscular system. Regardless, the significant relationships reported in this investigation were identified over the course of two weeks training only and neither subjective nor objective variables identified within-day trends. It is therefore recommended that future investigations track these variables over time and for individuals in order to see if they are over-training and not just over-reaching components.

CHAPTER 4: CONCLUSIONS & PRACTICAL RECOMMENDATIONS

The halfpipe cohort present numerous environmental, logistical and psychosocial factors which makes investigation into this sport very difficult. In so saying the newness of halfpipe athletes and coaches to science and regular training and periodisation practices lends itself to numerous avenues of both conventional knowledge application, and to future research directions. This section will firstly discuss practical recommendations for future research methodologies and secondly will provide several recommendations to coaching and sport science staff working directly with halfpipe athletes.

When using observational methodologies where the number of variables is considerable, the reliability and validity of assessment tools must be high. Based on the findings within this investigation it would be advisable to increase the inclusiveness of the observational methods and/or to use a more comprehensive fatigue protocol. For example if the target is identifying the demands of on-snow training over consecutive days, it would be advisable to include off-snow activity measures to ensure fatigue measured is actually due to on-snow activity. No control for off-snow activity and recovery at night was done in this study, nor was there an attempt to identify the phase of training the athletes were performing in. It may have been that those exhibiting reduced capabilities across the week were doing less recovery, and/or more conditioning work during this phase, skewing the data. It was assumed that the athletes were in a trick development stage where on-snow quality time is paramount to ensure good motor-learning and minimal risk of injury as high end and new tricks are worked on. However, those simply getting volume on prelearned tricks, will often sustain a greater off-snow training volume and/or intensity during these periods.

Once practitioners have a little more guidance from studies such as this which clarify the important variables and reliable assessment methods with this cohort, there may be opportunity for establishing a more rigorous fatigue assessment protocol. Being wary not to disrupt training sessions excessively, but using a set number of runs with standardised tricks and structured days on and off-snow, may allow a more reliable and standardised picture of what the fatigue impact of riding for certain durations involves.

As Sporer, Cote and Sleivert (2012) identified in their recent study of Snowboarder-cross athletes in competition, warm-up patterns of some snowsports athletes are not yet part of everyday practice. This was a strong consideration in this investigation, particularly of introducing a warm up protocol which may have been seen as excessive by our subjects. Indeed, the warm-up was designed to minimise the impact on the athletesô training session. However, while this warm-up was standardised and well adhered to, it was not as long as those used in clinical settings, where researchers often use protocols of 10 to 20 minutes. This protocol may have been insufficient to overcome early morning power reduction due to diurnal body temperature effects (Cronin et al., 2004; Markovic et al., 2004; Taylor et al., 2011).

While time of day may affect body temperature through diurnal variations, logistical issues of warm-up and interruptions to the normal sport settings were also a consideration. The protocol used in this investigation (three jumps with one minute between trials) appears the standard in the literature, especially with observational studies (Feltner et al., 2004; Markovic et al., 2004). Unfortunately however, it was observed that subjects were anxious not to wait excessively long between bouts, were less inclined to care for technique and effort earlier in the day, and as a consequence subjects commonly had to be asked to repeat their efforts during morning sessions.

Ensuring robust familiarisation procedures, and that subjects had at least 2-3 high effort jumps which were observed for technique prior to testing is, important especially with a new technique, new cohort and/or maximal testing. Furthermore, reminding subjects of the need for good warm ups and the need for maximum effort should be reinforced. Practically, limiting objective measurement, (which is reliant on maximal effort and effective warm-ups), to post-session timeframes where athletes are both warm, less time pressured and may be less distracted by their impending session may be worthwhile if using these measures over consecutive days.

Regardless of measurement intervention, off-snow warm-ups do not seem to be seen as important by many halfpipe riders, who often prefer to warm up on-snow over several laps. Arguably there is room for development here when targeting maximal quality time on snow, minimising injury early in the session and if considering future pre-session objective research. Valuable future research directions include identifying an effective warm up structure that snowsports athletes and coaches buy into.

Considering the significant findings with respect to the pre-session LPF being negatively related to continued time on snow, it could be recommended that coaches use this self-report measure to track their athleteǿs fatigue as well as to guide decisions regarding session content and length. By monitoring individuals over time, coaches and athletes may identify LPF thresholds beyond which they agree to change or even cancel a training session. A scale of motivation to train could also be a useful and quick tool pre-session to aid in session planning.

Following training, athletesô RPE still appears a useful tool for identifying load. Considering that the results of this study indicate that the LPF and RPE scales measure distinctly different variables, using both of them post session, along with a complementary measure such as session effectiveness or heart rate, could be a powerful planning tool for coaches and a monitoring tool for scientists. Again, such tools could be used in the short term to establish thresholds agreed between athlete and coach, and/or simply observed long term in order to make more informed planning decisions for future training.

One thing to note is that when using subjective scales it is important to ensure understanding and congruency, limiting the use of different scales over multiple timeframes. For example the use of 0-100% and 1-10 (for LPF and RPE respectively) confused people during familiarisation. During this time some subjects identified LPF as the soreness of specific muscle groups rather than overall fatigue, while others considered that since it was morning, this was their baseline for the day and consequently gave a rating of 0% fatigue. Practitioners need to take the time to explain scales to individuals in their own language in order to gain clarity prior to recording ï especially if group norms are to be considered. Even RPE, which is one of the more common subjective scales used in rating activity, needs strict and clear explanation.

Using the GymAware LPT to measure MP and PV offers strong possibilities for monitoring athletes over consecutive days. However, while found to be reliable, jump protocols need to be strictly adhered to and not taken too casually. As identified, encouraging sufficient warm up protocols pre-session will not only assist in the quality of data collection but arguably will assist in athletesô quality training time on-snow.

The findings of this thesis suggests that tracking the subjective variables of intensity and fatigue and/or regularly monitoring MP and PV variables may be important in understanding the effect of training on individuals over time. If practitioners find post-session to pre-session relationships with factors in excess of those identified in Table 4, continuing after consecutive weeks and in combination with short rest intervals, it may be that their athletes are at risk of over-reaching and even over-training.

Future investigation is required to see if other dependant variables offer greater or lesser use than those reported. This investigation identified that aside from the reported variables of MP, PV and JH, the CVs for peak power, mean velocity and mean and peak force were also very reliable. These other variables were not included due to the volume of data collected and their high intercorrelations (not reported).

It also remains to be seen whether monitoring these variables by themselves would be best post-session only or in conjunction with pre-session measures (i.e. tracking a change variable as was done within this investigation). This investigation only reported the change in pre-post measures against the next dayôs subjective and objective measures. Considering the aforementioned logistical difficulty in pre-session measurement, using post-session objective measures and pre-session subjective measures may be the most practical, both for between-day and over longer term monitoring.

Intuitively there will be an amount of fatigue built up during a day of halfpipe training and indeed over consecutive days. This investigation failed to find anything to conclusively demonstrate that this fatigue was neuromuscular in origin and/or that it affected the kinetics of the athletes jumping over a dayȏs riding. Indeed the increase in post-session versus pre-session jumping was surprising. Although this investigation identified some alterations in jump performance, technique or movement patterns were not monitored. Altered movement patterns have regularly been reported in the literature as major contributors to joint injury, and as recently reported by Flørenes, Nordsletten, Heir, and Bahr (2012), joint injury has been found to account for around 1/3 of all injuries causing time off snow for snowsports athletes (Chappell et al., 2005; Flørenes et al., 2012; Thorlund et al., 2008). Identifying how halfpipe training affects kinematics could be a useful direction for future research. Moreover using jumping techniques more closely related to the movement context would be a recommendation, although such methodologies would need validation with this cohort.

REFERENCES

Argus, C. K., Gill, N. D., Keogh, J. W. L., Blazevich, A. J., & Hopkins, W. G. (2011). Kinetic and training comparisons between assisted, resisted, and free countermovement jumps. *Jounral of Strength and Conditioning Research, 25*(8), 2219-2227.

Arruza, J. A., Telletxea, S., Azurza, A., Balague, G., & Brustad, R. J. (2005). A Comparison of Physiological and Psychological Indicators in the Evaluation of the Work Capacity of Snowboarders. *Journal of Sport Behavior, 28*(2), 125-135.

Augustsson, J., Thomee, R., Linedn, C., Folkesson, M., Tranberg, R., & Karlsson, J. (2006). Single-leg Hop Testing Following Fatiguing Exercise: Reliability and Biomechanical Analysis. *Scandinavian Journal of Medicine and Science in Sports, 16*, 111-120.

Avalos, M., Hellard, P., & Chatard, J. (2003). Modeling the Training-Performance Relationship using a Mixed Model in Elite Swimmers. *Medicine and Science in Sport and Exercise, 35*(5), 838-846.

Bindner, S. R., & Greiger, K. M. (1999). The Downside of Snowboarding ï Common Injuries in Novices and those Seeking ñHospital Air". *Postgraduate Medicine, 105*(1).

Borresen, J., & Lambert, M. I. (2008). Quantifying Training Load: A Comparison of Subjective and Objective Methods. *International Journal of Sports Physiology and Performance., 3*, 16-30.

Cairns, S. P., Knicker, A. J., Thompson, M. W., & Sjogaard, G. (2005). Evaluation of Models Used to Study Neuromuscular Fatigue. *Exercise and Sport Sciences Reviews, 33*(1), 9-16.

Chappell, J. D., Herman, D. C., Knight, B. S., Kirkendall, D. T., Garrett, W. E., & Yu, B. (2005). Effect of Fatigue on Knee Kinetics and Kinematics in Stop-Jump Tasks. *The American Journals of Sports Medicine, 33*(7), 1022-1029.

Chatterton, R. T., Vogelsong, K. M., & Lu, Y. (1997). Hormonal Responses to Psychological Stress in Men Preparing for Skydiving. *Journal of Clinical Endocrinology and Metabolism, 82*(8), 2503-2509.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A Global Measure of Perceived Stress. *Journal of Health and Social Behavior, 24*(December), 385-396.

Cormack, S. J., Newton, R. U., McGuigan, M. R., & Dolyle, T. L. A. (2008). Reliability Measures Obtained During Single and Repeated Countermovement Jumps. *International Journal of Sports Physiology and Performance., 3*, 131-144.

Crewther, B., Cronin, J., & Keogh, J. (2005). Possible Stimuli for Strength and Power Adaptation: Acute Mechanical Responses. *Sports Medicine, 35*(11), 967-989.

Cronin, J., & Hansen, K. T. (2005). Strength and Power Predictors of Sport Speed. *Journal of Strength and Conditioning Research, 19*(2), 349-357.

Cronin, J., Hing, R. D., & McNair, P. J. (2004). Relaibility and Validity of a Linear Position Transducer for Measuring Jump Performance. *Jounral of Strength and Conditioning Research, 18*(3), 590-593.

Delorme, S., Tavoulris, S., & Lamonatagne, M. (2005). Kinematics of the Ankle Joint Complex in Snowboarding. *Journal of Applied Biomechanics, 21*, 394-403.

Drinkwater, E. J., Galna, B., McKenna, M. J., & Hunt, P. H. (2007). Validation of an Optical Encoder During Free Weight Resistance Movement and Analysis of Bench Press Sticking Point Power During Fatigue. *Journal of Strength and Conditioning Research, 21*(2), 510-517.

Engeser, S., & Rheinberg, F. (2008). Flow, Performance and Moderators of Challenge-Skill Balance. *Motivation and Emotion, 32*, 158-172.

Feltner, M. E., Bishop, E. J., & Perez, C. M. (2004). Segmental and Kinetic Contributions in Vertical Jump Performed with and Without an Arm Swing. *Research Quarterly for Exercise and Sport, 75*(3), 216-230.

Filaire, E., Bernain, X., Sagnol, M., & Lac, G. (2001). Preliminary Results on Mood State, Salivary Testosterone:Cortisol Ratio and Team Performance in a Professional Soccer Team. *European Journal of Applied Physiology, 86*, 179-184.

Flørenes, T. W., Nordsletten, L., Heir, S., & Bahr, R. (2012). Injuries among World Cup ski and snowboard athletes. *Scand J Med Sci Sports, 22*, 58-66.

Foster, C. (1998). Monitoring Training in Athletes with Reference to Overtraining Syndrome. *Medicine and Science in Sport and Exercise, 30*(7), 1164 -1168.

Foster, C., Florhaug, J. A., Franklin, J., Gottshcall, L., Hrovatin, L. A., Parker, S., . . . Dodge, C. (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research, 15*(1), 109-115.

Frederick, E. C., Determan, J. J., Whittlesey, S. N., & Hamill, J. (2006). Biomechanics of Skateboarding: Kinetics of the Ollie. *Journal of Applied Biomechanics, 22*, 33-40.

Gabbett, T. J. (2004). Influence of Training and Match Intensity on Injuries in Rugby League. *Journal of Sports Sciences, 22*, 409-417.

Gabbett, T. J., & Domrow, N. (2005). Risk Factors for Injury in Sub-Elite Rugby League Players. *The American Journals of Sports Medicine, 33*(3), 428-434.

Gabbett, T. J., & Domrow, N. (2007). Relationships Between Training Load, Injury, and Fitness in Sub-Elite Collision Sport Athletes. *Journal of Sports Sciences, 21*(13), 1507-1519.

Gabriel, H. H., Urhausen, A., Valet, G., Heidelbach, U., & Kindermann, W. (1998). Overtraining and immune system: a prospective longitudinal study in endurance athletes. *Medicine and Science in Sport and Exercise, 30*(7), 1151-1157.

Gandevia, S. C. (2001). Spinal and Supraspineal Factors in Human Muscle Fatigue. *Physiological Reviews, 81*(4), 1725-1789.

Hanley, J. A., Negassa, A., Edwardes, M. D., & Forrester, J. E. (2003). Statistical analysis of correlated data using generalized estimating equations: An orientation. *American Journal of Epidemiology, 157*(4), 364-375.

Harris, N. K., Cronin, J., Taylor, K.-L., Boris, J., & Sheppard, J. (2010). Understanding Position Transducer Technology for Strength and Conditioning Procticioners. *Strength & Conditioning Journal, 32*(4), 66-79.

Hart, L. (2002). Get Wise to Basic Mechanics of Snowboarding. *The Prorider*.

Hellhammer, D. H., Wust, S., & Kudielka, B. M. (2009). Salivary Cortisol as a Biomarker in Stress Research. *Psychoneuroendocrinology, 34*, 163-171.

Hilfiker, R., Hubner, K., Lorenz, T., & Marti, B. (2007). Effect of Drop Jumps Added to the Warm Up of Elite Sport Athletes with a High Capacity for Explosive Force Development. *Journal of Strength and Conditioning Research, 21*(2), 550-555.

Hopkins, W. G., Schabort, E. J., & Hawley, J. A. (2001). Reliability of Power in Physical Performance Tests. *Sports Medicine, 31*(3), 211-234.

Impellizzeri, F. M., Rampinni, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-Based Training Load in Soccer. *Medicine and Science in Sport and Exercise, 36*(6), 1042-1047.

James, C. R., Dufek, J. S., & Bates, B. T. (2006). Effects of Stretch Shortening Cycle Exercise Fatigue on Stress Fracture Injury Risk During Landing. *Research Quarterly for Exercise and Sport, 77*(1), 1-13.

Kajtna, T., Tusak, M., Baric, R., & S., B. (2004). Personality in High-Risk Sports Athletes. *Kinesiology, 36*(1), 24-34.

Kaufman, E., & Lamster, I. B. (2009). The Diagnostic Applications of Saliva - A Review. *Critical Reviews of Oral Biological Medicine, 13*(2), 197-212.

King, M. A., & Yeadon, M. R. (2004). Maximizing Somersault Rotation in Tumbling. *Journal of Biomechanics, 37*, 471-477.

Kipp, R. W. (1998). Physiological Analysis and Training for Snowboardôs Halfpipe Event. *Strength & Conditioning, 20*(4), 8-13.

Kivlighan, K. T., Granger, D. A., & Booth, A. (2005). Gender Differences in Testosterone and Cortisol Response to Competition. *Psychoneuroendocrinology, 30*, 58-71.

Knicker, A. J., Renshaw, I., Oldham, A. R., & Cairns, S. P. (2011). Interactive processes link the multiple symptoms of fatigue in sport competition. *Sports Medicine, 41*(4), 307-328.

Kuipers, H. (1998). Training and Overtraining: An Introduction. *Medicine and Science in Sport and Exercise, 30*(7), 1137-1139.

Leard, J. S., Cirillo, M. A., Katsnelson, E., Kimiatek, D. A., Miller, T. W., Trebincevic, K., & Garbalosa, J. C. (2007). Validity Of Two Alternative Systems For Measuring Vertical Jump Height. *Journal of Strength and Conditioning Research, 21*(4), 1296-1299.

Lehmann, M., Foster, C., & Keul, J. (1993). Overtraining in Endurance Athletes: A brief Review. *Medicine and Science in Sport and Exercise, 25*(7), 854-862.

Liebermann, D. G., & Katz, L. (2003). On the Assessment of Lower Limb Muscular Power Capebility. *Isokinetics and Exercise Science, 11*, 87-94.

Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental Fatigue Impairs Physical Performance in Humans. *Journal of Applied Physiology, 106*, 857-864.

Markovic, G., Dizdar, D., Jukio, I., & Cardinale, M. (2004). Reliability and Factorial Validity of Squat and Countermovement Jump Tests. *Journal of Strength and Conditioning Research, 18*(3), 551-555.

McArdle, W. D., Katch, F. I., & Katch, V. L. (1991). *Exercise Physiology, Energy, Nutrition, and Human Performance* (3 ed.). Malvern, P.A.: Lea and Febiger.

McGuigan, M. R., Doyle, T. L. A., Newton, M., Edwards, D., Nimphius, S., & Newton, R. U. (2006). Eccentric Utilisatoin Ration: Effect of Sport and Phase of Training. *Jounral of Strength and Conditioning Research, 20*(4), 992-995.

McLean, S. G., Felin, R. E., Suedekum, N., Calabrese, G., Passerallo, A., & Joy, S. (2007). Impact of Fatigue on Gender-Based High Risk Landing Strategies. *Medicine and Science in Sport and Exercise, 39*(3), 502-514.

Morgan, W. P., Brown, D. R., Raglin, J. S., O'Connor, P. J., & Ellickson, K. A. (1987). Psychological Monitoring of Overtraining and Staleness. *British Journal of Sports Medicine, 21*(3), 107-114.

Morton, R. H. (1997). Modeling Training and Overtraining. *Journal of Sports Sciences, 15*, 335-340.

Moyle, G. M., & Terry, P. C. (2005). *Psychological Predictors of Injury in Elite Athletes.* Paper presented at the ISSP 11th World Congress of Sport Psychology, Sydney, Australia.

Myer, G. D., Ford, K. R., Brent, J. L., & Hewett, T. E. (2006). The Effects of Plyometrics vs Dynamic Stabilization and Balance Training on Power Balance and Landing Force in Female Athletes. *Journal of Strength & Conditioning Research, 20*(2), 345-353.

O'Shea, M. J. (2004). Snowboard Jumping, Newton's Second Law and the Force on Landing. *Physics Education, 39*(4), 335-341.

Petibois, C., Cazorla, G., Poortmans, J.-R., & Deleris, G. (2003). Biochemical Aspects of Overtraining in Endurance Sports: The Metabolism Alteration Process Syndrome. *Sports Medicine, 33*(2), 83-94.

Platzer, H.-P., Raschner, C., Patterson, C., & Lembert, S. (2009). Comparison Of Physical Characteristics And Performance Among Elite Snowboarders. *Jounral of Strength and Conditioning Research, 23*(5), 1427-1432.

Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W. (2004). An Acute Bout of Static Stretching: Effects on Force and Jumping Performance. *Medicine and Science in Sport and Exercise, 36*(8), 1389-1396.

Presland, J. D., Dowson, M. N., & Cairns, S. P. (2005). Changes of Motor Drive, Cortical Arousal and Perceived Exertion Following Prolonged Cycling to Exhaustion. *European Journal od Applied Physiology, 95*, 42-51.

Rietjens, G. J. W. M., Kuipers, H., Adam, J. J., Saris, W. H. M., Breda, E. v., Hamont, D. v., & Keizer, H. A. (2005). Physiological, Biochemical and Psychological Markers of Strenuous Training-Induced Fatigue. *International Journal of Sports Medicine, 26*(1), 16-26.

Ross, A., Leveritt, M., & Riek, S. (2001). Neural Influences on Sprint Running: Training Adaptations and Acute Responses. *Sports Medicine, 31*(6), 409-425.

Santello, M. (2005). Review of Motor Control Mechanisms Underlying Impact Absorption from Falls. *Gait and Posture, 21*, 85-94.

Santello, M., McDonagh, M. J. N., & Challis, H. H. (2001). Visual and Non-Visual Control of Landing Movements in Humans. *Journal of Physiology, 537*(1), 313-327.

Sporer, B. C., Cote, A., & Sleivert, G. (2012). Warm-Up Practices in Elite Snowboard Athletes. *International Journal of Sports Physiology and Performance, 7*, 295-297.

Stewart, A. M., & Hopkins, W. G. (2000). Seasonal Training and Performance of Competitive Swimmers. *Journal of Sports Sciences, 18*, 873-884.

Strojnik, V., & Komi, P. V. (1998). Neuromuscular Fatigue After Maximal Stretch-Shortening Cycle Exercise. *Journal of Applied Physiology, 81*(1), 344-350.

Tarazi, F., Dvorak, F. S., & Wing, P. C. (1999). Spinal Injuries in Skiers and Snowboarders. *The Americal Journal od Sports Medicine, . 27*(2), 177-180.

Taylor, K.-L., Cronin, J., Gill, N. D., Chapman, D. W., & Sheppard, J. (2011). Warm-Up Affects Diurnal Variation in Power Output. *International Journal of Sports Medicine, 32*, 185-189.

Terry, P. C., & Lane, A., M. (2003). *User Guide for the Brunel Mood Scale (BRUMS)*. University of Southern Queensland.

Terry, P. C., Lane, A. M., Lane, H. J., & Keohane, L. (1999). Development and Validation of a Mood Measure for Adolescents. *Journal of Sports Sciences, 17*, 861-872.

Thorlund, J. B., Michalsik, L. B., Madsen, K., & Aagaard, P. (2008). Acute Fatigue Induced Changes in Muscle Mechanical Properties and Neuromuscular Activity in Elite Handball Players Following a Handball Match. *Scandinavian Journal of Medicine and Science in Sports, 18*, 462-472.

Tomazin, K., Dolenec, A., & Strojnik, V. (2008). High-Frequency Fatigue After Alpine Slalom Skiing. *European Journal of Applied Physiology, 103*, 189-194.

Turnbull, J. R., Keogh, J. W. L., & Kilding, A. E. (2011). Strength and Conditioning Considerations for Elite Snowboard Halfpipe. *The Open Sports Medicine Journal, 5*, 1-11.

Turnbull, J. R., Kilding, A. E., & Keogh, J. W. L. (2009). Physiology of Alpine Skiing. *Scandinavian Journal of Medicine and Science in Sports, 19*, 146-155.

Virmavirta, M., Kivekas, J., & Komi, P. A. (2001). Takeoff Aerodynamics in Ski Jumping. *Journal of Biomechanics, 34*, 465-470.

Wikstrom, E. A., Powers, M. E., & Tillman, M. D. (2004). Dynamic Stabilization Time After Isokinetic and Functional Fatigue. *Journal of Athletic Training, 39*(3), 247-253.

Wu, Q., Igci, Y., Andreopoulos, Y., & Weinbaum, S. (2006). Lift Mechanics of Downhill Skiing and Snowboarding. *Medicine and Science in Sport and Exercise, 38*(6), 1132-1146.

Yamakawa, H., Murase, S., Sakai, H., Iwama, T., Katadaka, M., Niikawa, S., Sumi, Y., Nishimura, Y., Sakai, N. (2001). Spinal Injuries in Snowboarders: Risk of Jumping as an Integral Part of Snowboarding. *The Journal of Trauma, Inury, Inrection and Critical Care, 50*, 1101-1105.

Zacharaopoulos, A. N., Tzanakakis, N., & Mitsou, A. (2004). Injury Types in Skiing and Snowboarding ï The Greek Experience. In 15th ISSS Conference in Pontresina, Switzerland 27 April to 2 May 2003. *Knee Surgery, Sports Trauma and Arthroscopy, 12*, 169-177.

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APPENDICES

APPENDIX A: PARTICIPANT INFORMATION SHEET

Participant Information Sheet

Date Information Sheet Produced:

September 1st 2011

Project Title

The Relationship between Training Load and Explosive Power as Measures of Training Induced Fatigue in Snowboard and Freeski Halfpipe

An Invitation

Dear members of the Winter Performance Programme (WPP) Olympic Park and Pipe Programme Spring Camp. You are hereby invited to participate in a research project designed to identify fatigue components of halfpipe training. The data collected during this research project will be used to contribute toward my (Jon Turnbull) Masters in Sport & Recreation.

If you accept this invitation to a participate in the project, you do so voluntarily and may at any stage withdraw yourself or any information that you have provided for this project at any time prior to completion of data collection - without being disadvantaged in any way. While the Spring Camp is part of the WPPȏs annual training plan, there is no link to funding or selection as a result of your participation or the data being collected in this project. Any publicised results will at no time mention your name or corresponding personal details. Any results shared with the coach will only be shared upon verbal acceptance by yourself.

What is the purpose of this research?

This project will collect data for use in a study on fatigue and training load in halfpipe training. The data collected will contribute toward Jon Turnbullôs Masters (Thesis) and may also be utilised in a published journal following its acceptance by Auckland University of Technology as a Masterôs Thesis.

The project specifically aims to examine the relationship between explosive power, as a measure of training induced fatigue, and training load during normal halfpipe training.

How was I identified and why am I being invited to participate in this research?

You have been invited into this investigation because: of your involvement in the Cardona Spring Camp as a member of your nations Elite halfpipe programme, you are deemed Elite by international standards and; you are targeting either the 2014 and/or 2018 Olympic Winter Games.

As part of your inclusion we will consider your Nations standard medical screening and biomechanical assessments which involve a thorough history and assessment of injury, illness and movement quality ï this is to ensure there are no negative implications (such as worsening existing injuries) that could occur as a result of testing and/or could negatively affect the testing reliability or your full participation in the camp.

Please note that your results and/or participation may need to be excluded if you are unable to consistently train and/or if injury disallows you to safely participate in the testing sessions over the course of the project. The WPP team physiotherapist will be present during all on-snow training to ensure injury status (any variation from initial assessment) is monitored accordingly.

What will happen in this research?

As a participant of this project you will be required to undergo two short testing sessions each day. There will be a pre-session and post-session explosive power test and report of the level of your perceived fatigue (LPF) taken pre-session and the intensity of your training session (RPE) following training each day.

In the morning testing, prior to going on snow, you will perform your standardized warm up including dynamic stretching and light aerobic work as is standard in the WPP Teams. You will not have to do this following your on-snow training session considering you will be warm from the session ï you may however choose to. Figure 1 outlines the full procedure for each testing day:

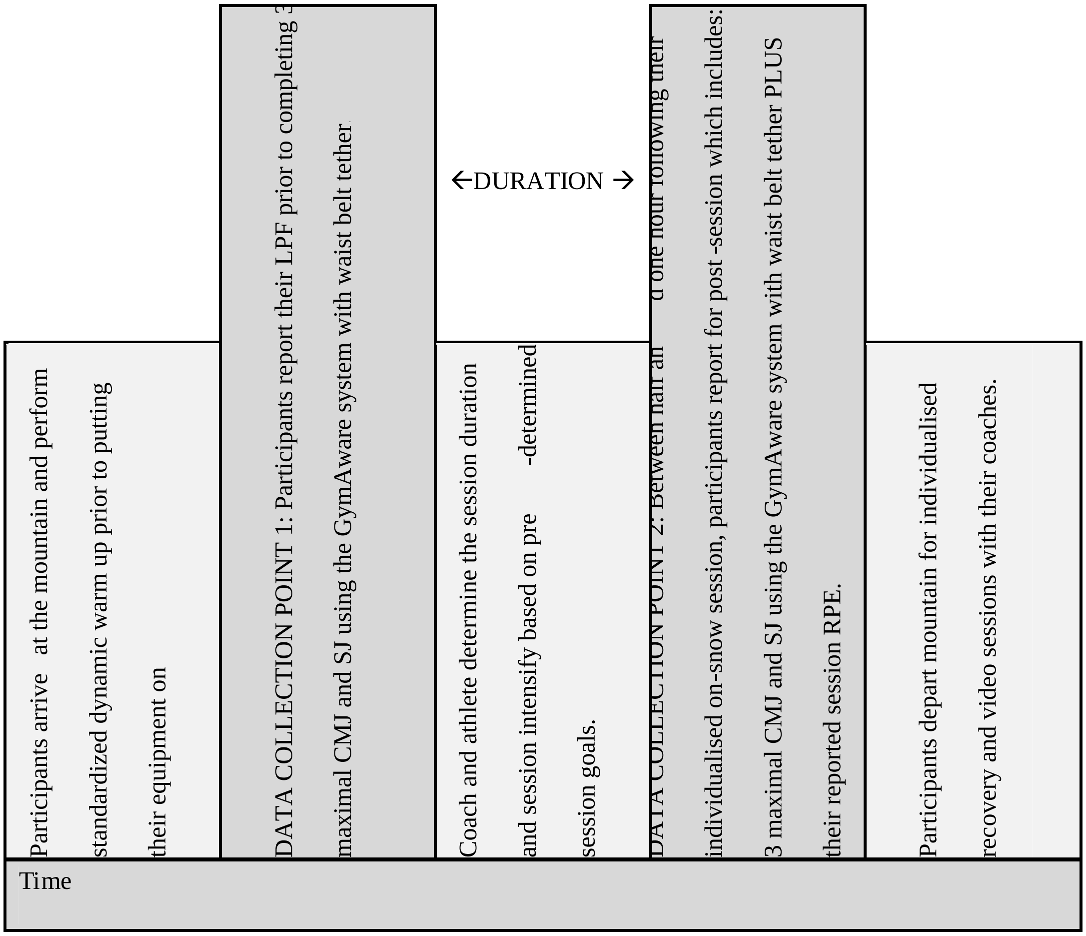

Figure 1. Overview of daily testing procedure of pre and post-session explosive power testing with recording of participant RPE during the post-session testing.

Qualitative Measures of Fatigue – Load.

During your pre-session explosive power testing you will be asked to rate your Level of Perceived Fatigue (LPF) based on a percentage (0% being absolutely no fatigue). Upon finishing your on-snow training session you will be allowed up to half an hour to change, debrief with your coach and to rehydrate before performing your post session testing. Immediately prior to each post session explosive power test, you will be asked to provide your rating of perceived exertion (RPE) score indicating the level of intensity for the whole training session using the question: ñhow hard was the session?ò See Figure 2 below. We will calculate the duration of your session and then multiplying the duration by your intensity (RPE) we gain a measure of the Load of your session.

0	*Rest*
1	*Really easy (Very,`very easy)*
2	*Easy*
3	*Moderate*
4	*Sort of hard (somewhat hard)*
5	*Hard*
6	
7	*Really hard*
8	
9	*Really, really hard*
10	*Just like my hardest race ever (Maximal)*

Figure 2. Rating of Perceived Exertion Adapted from Foster et al (2001)

Quantitative Measure of Fatigue – Explosive Power Tests:

Pre session and post session explosive power variables will be measured using a Countermovement (CMJ) and a squat jump (SJ). You will wear a light waist belt onto which a cord will be attached from a Gym Aware, Optical encoder system (Kinetic Performance Technology, Canberra, Australia). This device captures velocity and distance travelled of the cord and it is from these measures we can calculate a number of power variables. The difference between pre and post session testing is assumed to be an indication of fatigue ï the component we are interested in for this study.

You will perform three maximal vertical jumps for each jump, with one minute between trials with the best 2 jumps being taken for analysis. Your hands will be placed on your hips during all jumps. And your aim is to jump as high as possible. You will need to ensure you leave the mat and land with ankles, and knees fully extended (but not locked) to allow accurate determination of flight time. *It is important you provide maximal effort to jump as high as you can so that we can* *ensure the tests are valid and are a true indication of any fatigue you may have endured that day*. Please note the number of jumps have been minimised and the rest time maximised to ensure you do not fatigue yourself before your training session. Every attempt has been made to ensure this project does not interfere with your on snow training at all throughout the camp. If you have any concerns throughout the camp please do not hesitate to discuss these with your coach or the researcher (contact details outlined below.

What are the discomforts and risks?

Considering both of these jumps are standard within halfpipe training methodologies and that they are fairly similar to movements you do on the snow, there should be little discomfort or learning affect from these jumps.

The design of the projects has occurred with specific attention to both minimising the time it takes to gather data (i.e. to do the tests) and the fatigue which could be caused by maximally testing. We have allowed large rest periods to reduce fatigue but not interrupt your training session overly and we have included the minimum number of jumps to record reliable data. At the most you will do 6 maximal jumps prior to an on snow training session.

What are the benefits?

Benefits to the Athlete and the Sport:

Investigation into halfpipe training has both performance enhancement and injury prevention benefits. Injury epidemiology and prevalence studies of snowboarding halfpipe report a high level of landing and jumping based impact injury to the ankle, knee and spine. Understanding the effect of a single training session as well as repeated training sessions on neuromuscular capability, is an important facet of minimizing the risk of these types of injury through appropriate session planning.

From a performance perspective, if the findings of this investigation validate qualitative measures (LPF, RPE, Load) relative to quantitative markers of fatigue (explosive power tests), coaches may more effectively use and trust this athlete-report application. Furthermore if coaches and athletes are more aware of the amount and type of fatigue built up during normal training (in this instance explosive power), they may make more informed decisions regarding: individualized session planning; when to cease a training session or when to persevere; and how long athletes need between training sessions.

Reducing the risk of acute injury and chronic overuse/overtraining is of direct relevance not only to coaches, conditioners and physiotherapists but to wider stakeholders such as Accident Compensation Corporation (ACC) who take financial responsibility for injury. Fatigue has strong associations with increased susceptibility to injury both acutely due to alterations in neuromuscular control and to longer term overtraining based overuse injury.

Benefits to the researcher:

The data collected during this project will contribute towards a Thesis to be submitted for Masters qualification by the research Jon Turnbull.

How will my privacy be protected?

Your day to day results for pre and post session measures will be provided to you after the last jump test each day. Following the completion of the camp you will be provided a small summary report and a simple explanation of the results within 1 week of the last day of the camp. A final written report will be distributed to your coaches and the WPP staff to benefit the development and planning of future training sessions. As with published data no individual participantôs results will be able to be identified in the final report. Your individual coach will be allowed access to your data and results *only following your consent*.

What are the costs of participating in this research?

There is absolutely no cost to being involved in the project or in obtaining your individual results following the project. Obviously your time (before and after your normal on-snow training session) will be required. However as stated this will be minimal and is designed not to interfere with your training at all. Please remember though that we do need maximal effort for all your jumps.

What opportunity do I have to consider this invitation?

The spring Camp will occur from 3rd to the 16th October. You will have the entire post-competition period (September) to consider your inclusion, so take the time to consider and ask questions of the researcher or your coach during this time.

How do I agree to participate in this research?

If you agree to participate in this project, please sign the consent form attached to this information sheet. If there is none attached contact Jon Turnbull (details below) or your coach to obtain one.

Will I receive feedback on the results of this research?

Following the completion of the camp a small summary report and a simple explanation of the results will be provided to you. A final written report will be distributed to yourself and, the coaches to benefit the development and planning of future training sessions. As with published data no individualôs results will be able to be identified in the final report. Finally any published papers on this topic will be available from the researcher at any stage also.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, **Dr Nigel Harris, PhD, Senior Lecturer, School of Sport and Recreation, PHONE +64 9 921 9999 extn 7301.**

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, **Madeline Banda, madeline.banda@aut.ac.nz , 921 9999 ext 8044.**

Whom do I contact for further information about this research?

Jon Turnbull, Jon_T@xtra.co.nz, 021` 222 7246.

Approved by the Auckland University of Technology Ethics Committee on 30 July 2012, AUTEC Reference number 11/238.

APPENDIX B. PARTICIPANT CONSENT FORM

Consent Form

For use when laboratory or field testing is involved.

Project title: The Relationship between Training Load and Explosive Power as Measures of Training Induced Fatigue in Snowboard and Freeski Halfpipe

Project Supervisor: Dr Nigel Harris, PhD. Senior Lecturer, School of Sport and Recreation

Researcher: Jon Turnbull. Faculty of Health and Environmental Sciences.

○ I have read and understood the information provided about this research project in the Information Sheet dated 24-9-2011.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.

○ I understand that there is no link to funding or selection as a result of the data being collected in this study and that any publicised results will at no time mention my name or corresponding personal details.

○ I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection. I will consult with my team physiotherapist if I have any concerns about training or participating in this study.

○ I agree to provide maximal effort when participating in the jump testing.

○ I agree to take part in this research.

○ I wish to receive a copy of the report from the research (please tick one): Yes○ No○

Participants Signature:é é

Participants Name:é é

Participants Contact Détails (if ppropriate):é é

Date:

Note: The Participant should retain a copy of this form.

APPENDIX C. SCALES FOR PARTICIPANT INFORMATION: RPE

Rating of Perceived Exertion - RPE

“How hard was your session?”

0	***Rest***
1	***Really easy (Very,`very easy)***
2	***Easy***
3	***Moderate***
4	***Sort of hard (somewhat hard)***
5	***Hard***
6	
7	***Really hard***
8	
9	***Really, really hard***
10	***Just like my hardest session ever (Maximal)***

Level of Perceived Fatigue - LPF

“What is your current level of fatigue/exhaustion?”

0 – 10%	*(No Fatigue)*
10 – 20%	
20 – 30%	
30 – 40%	
40 – 50%	
50 – 60%	
60 – 70%	
70 – 80%	
80 – 90%	
90 – 100%	*(Completely exhausted)*

APPENDIX E. ETHICS APPROVAL

M E M O R A N D U M

Auckland University of Technology Ethics Committee (AUTEC)

To: Nigel Harris
From: Rosemary Godbold, Executive Secretary, AUTEC
Date: 30 July 2012
Subject: Ethics Application Number **11/238 The relationship between training load and explosive power as measures of training induced fatigue in snowboard and freeski halfpipe.**

Dear Nigel

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 12 September 2011 and I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTECôs *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement by AUTEC at its meeting on 13 August 2012.

Your ethics application is approved for a period of three years until 30 July 2015.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 30 July 2015;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/research/research-ethics/ethics. This report is to be submitted either when the approval expires on 30 July 2015 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

To enable us to provide you with efficient service, we ask that you use the application number and study title in all written and verbal correspondence with us. Should you have any further enquiries regarding this matter, you are welcome to contact me by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 6902. Alternatively you may contact your AUTEC Faculty Representative (a list with contact details may be found in the Ethics Knowledge Base at http://www.aut.ac.nz/research/research-ethics/ethics).

On behalf of AUTEC and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Dr Rosemary Godbold
Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Jonathon Turnbull jon_t@xtra.co.nz