Effect of exercise intensity on shooting performance in the sport of Summer Biathlon
by Brian Keith Higginson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Health and Human Development
Montana State University

Abstract:
The purpose of this study was to determine the effect of running intensity on shooting performance in summer biathletes by comparing shooting scores immediately following bouts of exercise at four different intensities in an effort to determine if running intensity can be maintained, or increased, without a subsequent decrement in shooting performance.

Each subject (seven elite and three novice) was required to shoot five shots at paper targets immediately following bouts of exercise at four different intensities. Exercise intensities included shooting with a resting heart rate (INTI), slowing to 75% of race pace (INT2), maintaining race pace (INT3), and sprinting (INT4). All subjects began testing by shooting five shots prone and five shots standing at INTI. All subsequent conditions were counterbalanced for intensity and position. A one kilometer loop was run between shooting bouts with changes in exercise intensity (INT2-INT4) occurring 50 meters prior to entering the range. Measures of shooting performance included the number of shots hit (SH), shooting accuracy (SA), and shooting precision (SP).

As intensity increased from INT2 to INT4, there was a, significant decrease (pO.OOl) in 50 meter run time prior to entering the range (12.52 s vs. 8.96 s, respectively), with no difference in one kilometer run times (p=0.50). Although an , increase in exercise intensity was associated with a decrease in SH for both the prone and standing position, there was no significant difference in SH for the elite subjects (N7), or all subjects as a group (N10), as a result of position (N7: p=0.64, N10: p=0.86) or intensity (N7: p=0.10, N10: p=0.12). A significant interaction effect was found in N7 for the SA measure of shooting performance (p=0.005), as well as a significant difference in both position (p<0.00l) and intensity (p=0.008) for the SP measure. SA for NlO was significantly different for both position (p<0.001) and intensity (p=0.009). There was no difference between N7 and NlO for the SP measure of shooting performance.

These preliminary findings indicate that race times may be decreased in the sport of summer biathlon by as much as 7.12 seconds in a 5 km race without a subsequent compromise in shooting performance.

EFFECT OF EXERCISE INTENSITY ON SHOOTING PERFORMANCE IN THE SPORT OF SUMMER BIATHLON

by

Brian Keith Higginson

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Health and Human Development

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2002

APPROVAL

of a thesis submitted by

Brian Keith Higginson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Daniel P. Heil, PhD Daniel P. Heil 4/17/02
(Signature) Date

Approved for the Department of Health and Human Development

Ellen Kreighbaum, PhD Ellen Kreighbaum 4/17/02
(Signature) Date

Approved for the College of Graduate Studies

Bruce McLeod, PhD Bruce R. McLeod 4-22-02
(Signature) Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature ____________

Date 4\22\02

TABLE OF CONTENTS

TABLE OF CONTENTS-CONTINUED

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this study was to determine the effect of running intensity on shooting performance in summer biathletes by comparing shooting scores immediately following bouts of exercise at four different intensities in an effort to determine if running intensity can be maintained, or increased, without a subsequent decrement in shooting performance.

Each subject (seven elite and three novice) was required to shoot five shots at paper targets immediately following bouts of exercise at four different intensities. Exercise intensities included shooting with a resting heart rate (INT1), slowing to 75% of race pace (INT2), maintaining race pace (INT3), and sprinting (INT4). All subjects began testing by shooting five shots prone and five shots standing at INT1. All subsequent conditions were counterbalanced for intensity and position. A one kilometer loop was run between shooting bouts with changes in exercise intensity (INT2-INT4) occurring 50 meters prior to entering the range. Measures of shooting performance included the number of shots hit (SH), shooting accuracy (SA), and shooting precision (SP).

As intensity increased from INT2 to INT4, there was a significant decrease ($p<0.001$) in 50 meter run time prior to entering the range (12.52 s vs. 8.96 s, respectively), with no difference in one kilometer run times ($p=0.50$). Although an increase in exercise intensity was associated with a decrease in SH for both the prone and standing position, there was no significant difference in SH for the elite subjects (N7), or all subjects as a group (N10), as a result of position (N7: $p=0.64$, N10: $p=0.86$) or intensity (N7: $p=0.10$, N10: $p=0.12$). A significant interaction effect was found in N7 for the SA measure of shooting performance ($p=0.005$), as well as a significant difference in both position ($p<0.001$) and intensity ($p=0.008$) for the SP measure. SA for N10 was significantly different for both position ($p<0.001$) and intensity ($p=0.009$). There was no difference between N7 and N10 for the SP measure of shooting performance.

These preliminary findings indicate that race times may be decreased in the sport of summer biathlon by as much as 7.12 seconds in a 5 km race without a subsequent compromise in shooting performance.

CHAPTER ONE

INTRODUCTION

In the sport of biathlon, it is not uncommon for top-ten finishes of elite competitors to be decided by a matter seconds. The 2000 US National Biathlon Championships is a prime example of this. The difference between 2^{nd} and 3^{rd} place was a mere three tenths of a second. A one-minute difference could have potentially moved the 24^{th} place finisher up to 14^{th} place. With competition this tight it is apparent that a need exists for elite biathletes to find a way to decrease their race times by even the smallest of margins. Being able to take two seconds off a 25 minute race could potentially mean the difference between a first and second place finish.

Historical Background

The name "biathlon" is a Greek word meaning two tests, and combines two skills with entirely different requirements (Niinimaa 1988). Biathlon is an Olympic winter sport combining the endurance of cross country skiing and the precision of rifle marksmanship. The origins of Biathlon have been traced as far back as 3000 BC where rock paintings depicted hunters with bow and arrows moving on "sliding timbers". However, the first written descriptions of hunting on skis came from Roman, Greek, and Chinese historical writings in 400 BC. Traditional military patrol races, the most commonly recognized origins of Biathlon, came into being in the Middle Ages. Skiing regiments were becoming active in Scandinavia and Russia in the 1500's, and by the end of the 19th century, Germany, Austria, and Switzerland were also beginning to see soldiers on skis.

Although the first recorded "Biathlon" competition took place between Swedish and Norwegian border patrol units in 1767, it was not until the first Winter Olympic Games in Chamonix, France in 1924 that the military ski patrol race was introduced as a demonstration sport. Individual events did not occur until the 1960 Winter Olympic Games in Squaw Valley, CA, when the first Mens Individual 20 km Biathlon made its debut. Up until 1977 only large bore (30.06, .308, and .243 cal) rifles were used for competition, since then only small bore (.22 cal) rifles have been allowed. The change to small bore rifles was made primarily to make the sport more accessible to a wider range of competitors, in addition to saving money on ammunition and targets and decreasing the space required to hold competitions. Although it is still a relatively obscure sport in the United States, with around 1,000 competitors nationwide, it is the most popular televised winter sporting event in Europe.

Traditionally, Winter Biathlon has been the most widely recognized form of biathlon. However, in the early 1980's the sport of Summer Biathlon was introduced as a way for winter biathletes to stay in shape and, as a result, has rapidly increased in popularity over the last decade. The main reason for this is that it incorporates running instead of skiing. Therefore more people are able and willing to participate since it requires less of a financial obligation by the athlete than winter biathlon, and more race venues are available since most climates facilitate running during the summer months.

Summer Biathlon race distances are typically five to eight kilometers (km) in length and consist of either two or four shooting bouts, with one to two and a half kilometer loops run between bouts. Shooting bouts alternate between the prone and standing (off-hand) shooting positions, starting with the prone. Targets are located 50 m from the firing line with target diameters of 40 millimeters (mm) and 110 mm for prone and standing, respectively. Five shots are allowed to hit five targets, with either a 100 m penalty lap assessed for missed targets, or a time penalty in the case of some of the longer events. Winners are determined by the shortest elapsed race time, regardless of shooting score.

Unlike most shooting sports in which success is based on accuracy (proximity of shot to center of target), shooting performance in the sport of summer biathlon is based on a hit or miss system. As long as each shot falls within the 40 mm and 110 mm diameter target for the prone and standing shooting positions, respectively, it is considered a hit. This method of scoring tends to favor the biathlete best able to minimize their shot group (proximity of shots in relation to each other), and maximize their accuracy, thereby facilitating a greater margin of error while shooting.

Since the sport of Summer Biathlon incorporates running and shooting, overall race times can be reduced by either improving running performance, increasing shooting accuracy, or a combination of both. Although there are numerous studies on improving running performance, as well as the effects of heart rate, breathing, and muscle fatigue on competitive position shooters, very little research has been done on the effects of these variables in combination as they relate to the sport of biathlon. The limited research in this area may be a function not only of the relative obscurity of the sport, but also the difficulty in measuring the various physiological parameters associated with the sport in a field setting. Researchers such as Hoffman, Gilson, Wetenburg, and Spencer (1992), and Groslambert, Candau, Belli, Gilliot, and Roillion (1997) have addressed the limitations of biathlon research conducted in the lab. Even though it may be easier to collect physiological data in the lab, the applicability of these results to actual race conditions are questionable.

Currently, it is common for elite biathletes to decrease their running speed prior to entering the shooting range in an effort to decrease both respiratory and heart rate. This decrease in respiratory and heart rate is believed to result in better overall shooting performance by limiting the amount of rifle movement while shooting. It has recently been suggested, however, that an increased intensity of exercise immediately prior to shooting has minimal effect on shooting performance in elite-level winter biathletes (Niinima 1988; Hoffman et al., 1992; Soldatov 1983). Soldatov reported that if an athlete is able to enter the shooting range at a greater intensity, yet maintain satisfactory shooting performance, the potential exists to decrease race times by as much as 25-30 seconds in a 20 km race (winter biathlon). If this holds true, then it is likely that the greatest potential for improvement in performance (decreased race times) for the elite biathlete is to reduce the amount of time lost during the approach to the firing line. Since most previous research in this area has dealt with Winter Biathlon (Hoffman et al., 1992; Hoffman 1992; Groslambert et al., 1997; Soldatov 1983), it would be of interest to see if this strategy can be successfully applied to the sport of Summer Biathlon. Therefore, it was the purpose of this study to evaluate the relationship between exercise intensity and its subsequent effects on shooting performance in summer biathletes in a field (simulated race) setting. Shooting performance was measured using three variables: number of shots hit (SH); shooting accuracy (SA); and shooting precision (SP). Shooting performance was compared between four conditions: 1) Resting heart rate (INT1), in which shooting occurred prior to any exercise; 2) After running a one km loop at race pace (RP), then decreasing to 75% of RP 50 m prior to entering the shooting range (INT2); 3) Maintaining RP all the way into the shooting range (INT3); and 4) Sprinting the last 50m into the shooting range after running a one km loop (INT4).

Statement of Purpose

The purpose of this study was to determine the effects of running intensity immediately prior to shooting (last 50 m) on shooting performance in summer biathletes. This was achieved by comparing shooting scores immediately following bouts of exercise at the four different intensities (INT1, INT2, INT3, and INT4) in an effort to determine if running intensity (speed) immediately prior to shooting can be maintained, or increased, without a subsequent decrement in shooting performance.

Hypothesis

The mean shooting variables (SH, SA, SP) are not significantly different among the four levels of the independent variables (INT1, INT2, INT3, INT4) for the prone and standing positions.

$$\mathbf{H_o: \mu_{Pi} \neq \mu_{Pj}, \text{ and } \mu_{Si} \neq \mu_{Sj}}$$

$$\mathbf{H_a: \mu_{Pi} = \mu_{Pj}, \text{ and } \mu_{Si} = \mu_{Sj}}$$

Where: μ_P and μ_S are population means for shooting performance (SH, SA, SP) in the prone and standing position, respectively, with i and j representing any two levels of each dependent variable across the four intensity levels.

Limitations

1. The subjects' unfamiliarity with shooting under conditions required by the protocol could potentially affect shooting scores. Biathletes typically shoot at either a resting heart rate (during practice), or at a heart rate similar to that elicited in actual competition.
2. Due to the subjectivity of INT2 it was assumed that all subjects could accurately determine 75% of their race pace and reduce their speed accordingly and consistently for both INT2 conditions (prone and standing shooting positions).

Delimitations

1. The scope of this study was delimited to competitive biathletes from the Bozeman, Montana, community.
2. Since all shooting data was collected outdoors, attempts were made to minimize the affects of weather on shooting performance by not collecting data on days that were excessively cold or windy.
3. No sight adjustments were allowed once testing began.

Definitions

Accuracy: The distance of a shot from the center of the target.

Elite level: This category includes all individuals on the U.S. National, World, Olympic, or development teams. It may also include less experienced competitors who chose to race in this category, and is differentiated from Open level competitors through the use of smaller targets in the prone position.

Hit: A shot that results in the knocking down of a target. Shot must hit within a 40 mm and 110 mm diameter circle for prone and standing, respectively.

Misfire: Trigger is pulled, but the round fails to fire.

Miss: A shot that does not result in the knockdown of a target (i.e., shot does not fall within the 40 mm and 110 mm diameter circle for prone and standing, respectively).

Off-hand: Shooting position in which the competitor remains standing, more commonly referred to as the standing position.

Precision: Closeness of all shots in relation to each other. Typically measured by the smallest circle that encompasses all shots.

Prone: Shooting position in which the competitor is lying down.

Range: Shooting range where all shooting takes place.

Recovery: Arbitrary distance selected by each individual athlete prior to entering the range in which they slow down in an effort to decrease their breathing and heart rate.

Set-up time: Amount of time used to take the first shot once a competitor gets into the shooting position.

Zero: Action performed prior to competition in which all competitors make sight adjustments to their rifle.

Operational Definitions

Age Predicted Maximal Heart Rate:	220 minus current age in years.
Maximal Oxygen Consumption ($\dot{V}O_{2max}$):	The rate of oxygen utilization by working muscle tissue during heavy exercise. $\dot{V}O_{2max}$ is achieved by progressively increasing the level of exercise intensity until oxygen consumption plateaus, or changes very little, despite further increases in intensity.
Respiratory Exchange Ratio (RER):	The ratio of CO_2 produced to the volume of O_2 consumed during resting or steady state exercise conditions.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

Although there are numerous studies that address the individual sports of cross country skiing (Rundell 1996; Rundell and Bacharach, 1994), running (Conley 1981; Koeslag and Sloan, 1976; Rundell 1996), and shooting (Era, Konttinen, Mehto, Saarela, and Lyytinen, 1996; Helin, Sihvonen, and Hanninen, 1987; Konttinen and Lyytinen, 1992; Konttinen, Lyytinen, and Konttinen, 1995; Konttinen, Lyytinen, and Viitasalo, 1998a, 1998b; Lakie, Villagra, Bowman, and Wilby, 1995; Zatsiorsky and Aktov, 1990), there is limited research specifically addressing the integration of these components into the sport of biathlon. Of these studies, all pertain to winter biathlon, and most are strictly observational (Groslambert et al., 1997; Hoffman and Street, 1992), or experimentally controlled in a laboratory setting (Bozsik and Kaske, 1998; Groslambert, Candau, Hoffman, Bardy, and Rouillion, 1999; Groslambert, Grappe, Candau, and Rouillion, 1998; Hoffman et al., 1992). The lack of research in the sport of summer biathlon, particularly in a field setting under actual race conditions, prompted the current study.

Observational Studies

The Albertville Winter Olympic Games of 1992 gave Groslambert et al. (1997) an opportunity to look at the correlation between the installation phase (set-up time) of shooting and shooting performance. Groslambert observed 24 males competing on the 6 highest-ranked relay teams at the Olympic Games. A positive relationship was found between installation time and penalty time (shots missed) in the prone position. As the installation time increased, the more likely an individual was to miss the target. The opposite was found to be true for the standing position. As installation time increased, the number of missed shots decreased. This trend could be attributed to the fatigue associated with the high level of physical exertion immediately prior to shooting, decreasing the stability of hold. Due to this decreased stability of hold, and a smaller base of support afforded by the standing shooting position, postural control of the rifle can be increased by maximizing installation time. In conclusion, Groslambert recommended that elite level biathletes minimize installation time in the prone position, and adapt their installation time in the standing position to individual heart rate recovery to maximize shooting performance. Although he agrees with other investigators (Niinimaa 1988; Hoffman et al., 1992; Soldatov 1983) that overall race times for elite level biathletes can be decreased by maintaining skiing speed prior to shooting, he was in disagreement as to its magnitude.

Soldatov (1983) suggested that 24-30 seconds could be gained in a 20 km race by maintaining skiing speed prior to shooting, while Groslamberts' data shows a gain of only 10.2 seconds. There are two possible explanations for this discrepancy. The first being that since Groslamberts' was an observational study, individual recovery times were unable to be controlled and accounted for. Based on data from video analysis, the amount of time for the athlete to cover the last 50 m prior to entering the shooting range could be calculated. Therefore, if an athlete started recovery (slowing down) before that point, any loss of time associated with the decrease would not have been considered. Also, Groslambert collected data during a relay race, in which the competitors have an additional three rounds (eight rounds total) to hit five targets in each shooting bout. Therefore, it is not uncommon for biathletes in a relay race to come into the range at a higher intensity (speed) than they normally would since they know there is more room for error while shooting. This could account for the disparity between the two times since Soldatov studied time decreases during individual races (five shots per shooting bout).

Hoffman (1992) conducted a similar observational study on 14 members (five men, six women) of the US National Biathlon Team during an early season biathlon race series. Heart rate data were gathered throughout the race (18.4 and 14.8 km for men and women, respectively) to get a better understanding of the physiological demands of biathlon and the strategies used in approaching the shooting range. Hoffman found that heart rates decreased 10-12 beats per minute (bpm) over a time of approximately 50-60 seconds during the approach to the firing line. Upon arrival to the firing line heart rates between the two shooting positions were similar (85-87% of maximum heart rate) with minimum heart rates during firing around 20 bpm lower for the prone position than the standing. This lower minimum heart rate in the prone position is to be expected since more time is usually spent in this position, allowing for greater recovery. Also, less work is required by the heart in this position since venous return of the blood from the legs is not required to work against gravity, thereby decreasing peripheral resistance (Bevegard, Freyschuss, and Strandell, 1966; Stenberg, Astrand, Ekblom, Royce, and Stalin, 1967).

This decrease in peripheral resistance increases stroke volume which, in turn, decreases the number of times per minute the heart has to beat to pump a given volume of blood.

Although it would seem logical to assume that a larger stroke volume would result in greater rifle movement, a slower heart beat might allow for a longer period in which to stabilize the hold before shooting and facilitate timing of the shot with the cardiac cycle. Research has yet to be done in this area to ascertain whether the additional base of support (increased stability of hold) in the prone position is sufficient to overcome the increased movement associated with a greater stroke volume.

Experimental Studies

With the exception of Hoffman et al. (1992), most experimental research involving shooting performance in the sport of biathlon has focused on shooting stability in the standing position (Bozsik 1998; Groslambert et al., 1998; Groslambert et al., 1999; Niinimaa and McAvoy, 1983).

A force plate was utilized by Niinimaa (1983) to measure the influence of physical exercise simulating biathlon race intensities on body sway while in the standing shooting position. He tested a wide range of shooters, including biathletes (n=4), position shooters (n=4), and a control group, which had no previous shooting experience (n=4). He found a significant decrease in horizontal movement (sway) in the subjects with the most shooting experience. Although this agrees with other research on rifle hold stability (Era et al., 1996; Konttinen et al., 1998; Zatsiorsky 1990), he also concluded that a decline in ventilation, and subsequent reduction in rifle movement, does not improve standing stability. This contradicts the findings of Groslambert et al. (1998) who showed that decreased ventilation increased stability of hold.

Driven by reports from Niinimaa (1988) and Soldatov (1983) that elite biathletes should maintain race velocities (speed) into the shooting range, Hoffman et al. (1992) used 13 members (six male, seven female) of the US National Biathlon Team to study the effects of various exercise intensities on shooting performance in the prone and standing shooting positions. Each subject shot at rest, after exercising on a bicycle ergometer to 130, 150 , and 170 beats per minute, and again after maximal exercise. The number of hits for the prone condition was not significantly different among the resting and exercise conditions. In the standing position the number of shots hit were significantly lower in the three highest exercise conditions (condition 2 was not significantly different from either the resting or three highest exercise conditions). The use of a bicycle ergometer as an exercise modality was justified by Hoffman due to the convenience in performing this activity next to the firing line at an indoor shooting range. Unfortunately this modality effectively eliminates muscular fatigue in the arm muscles associated with cross-country skiing or running. Due to the importance of the upper extremities in maintaining rifle stability, especially in the standing position, the elimination of upper body fatigue using a cycle ergometer could potentially facilitate inflated shooting scores. To more accurately elucidate the effects of exercise intensity on shooting performance, tests of shooting performance need to be conducted utilizing similar modalities as those found in actual race conditions to elicit the required physiological responses.

Shooting Research

Contrary to what might be expected, Landers (1983) found an inverted-U relationship between shooting performance and heart rate (HR) in position shooters in the standing position, with shooting performance maximizing between 90 and 100 beats per minute (bpm). This is surprising in light of the fact that most shooters report that a HR over 50 bpm results in noticeable sight deviations in time with their cardiac cycle.

Hoffman et al. (1992) found similar results in biathletes in the standing shooting position. There was no significant difference between shooting scores at resting HR, compared to shooting scores at 130 bpm. Given Landers' inverted-U relationship this would be expected since a resting HR elicited approximately the same shooting score as 130 bpm in his position shooters. Unlike the standing position, Hoffman found no significant difference between prone shooting scores at 130, 150, and 170 bpm. This is probably due to the greater base of support provided by the prone shooting position. The increased base of support allows greater rifle stability so that shooting scores can be maintained even at elevated HRs. In light of these findings it is apparent that the relationship found by Landers can only be applied to the standing rifle position, even though this limitation was not specifically addressed in his work.

Numerous other studies have indicated that the most successful shooters not only have a lower HR at the time of triggering, but also time their triggering in relation to their cardiac cycle (Helin et al., 1987; Konttinen et al., 1992; Konttinen et al., 1998a). Helin et al. (1987) found that champion rifle shooters consistently fired toward the end of diastole, whereas beginner shooters fired either during systole or diastole. He concluded that the best time of triggering is during late diastole, when the relaxation of the heart has lasted for nearly the longest possible period. Although Landers (1983) recorded a greater magnitude of individual variability than Helin, he found that elite shooters tend to fire just before the heartbeat when averaged across all shots for all 62 of his subjects.

Heart Rate and Respiratory Effects

Due to the increased physiological demand placed on the human body at high levels of physical activity, respiratory rate is substantially elevated upon entering the range during a biathlon race. The most obvious implication related to a high respiratory rate is movement of the rifle during inspiration and expiration, resulting in a lower stability of hold (HS). It is for this reason that biathletes time their shots according to breathing patterns, usually taking one breath per shot. However, respiration also plays an indirect role in HS. It has been shown that respiration is a primary determinant of HR (Blanchard, Young, and Mcleod, 1972; Bonaduce et al., 1998; Brooke, Hamley, and Thomason, 1970; Hirsch and Bishop, 1981; Hnatiow and Lang, 1965; McFarland and Campbell, 1975; Puig et al., 1993; Sroufe 1971; Suggs 1966; Wescott and Huttenlocher, 1961; Whipp and Wasserman, 1973). These studies indicate that rapid shallow breathing decreases HR and HR variability (HRV), whereas slow deep breathing increases HR and HRV. Unfortunately, most of the research looking at the effects of rate and depth of breathing utilize protocols under resting conditions. Since the demand of the body to remove accumulated CO_2 may override any attempts to control respiration, application to the sport of biathlon may be questionable. This is one area that needs to be addressed and applied specifically to the sport. This information has the potential to greatly benefit the elite level biathlete since it may allow them to control their HR with respiratory rate (RR). Attempting to control for both simultaneously leaves the athlete either waiting for HR and RR cycles to coincide so that they can fire, or forces them to hold their breath until they choose an appropriate time in their cardiac cycle to shoot, effectively forcing the shot. This approach is potentially detrimental to the shooting performance of the athlete.

Summary

Currently there is no published research in the sport of summer biathlon. All of the experimentally controlled research done on winter biathletes have been performed in the lab and, therefore, have limited application to actual competition. The current study was undertaken to fill an obvious gap in the literature by systematically altering the physiological demands placed on summer biathletes immediately prior to shooting in order to observe the associated effects on shooting performance in simulated summer biathlon race conditions. This allows application of the findings to conditions indicative of actual competition.

CHAPTER THREE

METHODOLOGY

Subjects

Ten "low risk" subjects, as defined by the American College of Sports Medicine (ACSM 2000), volunteered to take part in the current study. The subjects participating in the study consisted of male (n=7) and female (n=3) biathletes with varying running and shooting experience. Seven of the subjects were elite-level biathletes with at least two years of competitive experience in the sport of summer biathlon, while three were novice competitors. Three of the seven elite biathletes also competed in winter biathlon. All subjects were right handed except for one elite-level biathlete. Each subject signed an Informed Consent Form reviewed by the Human Subjects Committee at Montana State University, which included a description of the testing procedures (Appendix A), and filled out a Biathlon Experience and Training Questionnaire (Appendix B). A health history questionnaire was administered to ensure subjects had no contraindications to the level of physical activity required by the protocol

Procedures

Subject testing was conducted on two separate days and consisted of a field and lab testing component. Shooting, heart rate, and running data were collected during the initial field test, while the lab component included signing the appropriate forms, collecting demographic data (age, height, weight, and gender), and administration of a maximal oxygen consumption ($\dot{V}O_{2max}$) test. In addition to providing descriptive information as to the cardiovascular fitness of the subjects, lab testing also served as an incentive for participation in the study. All subjects were asked to wear shoes and clothing indicative of what they would normally wear during competition, and were required to wear the same shoes for all days of testing.

Field Testing

During the initial visit, shooting data were collected at the biathlon range located at Bohart Cross Country Ski Ranch in Bozeman, MT (elevation 1,935 m). This location was selected because it facilitated sustained, level terrain immediately prior to the shooting range, decreasing the effects that an uphill or downhill approach may have on heart rate response during testing. In an effort to minimize running detraining effects coming off the winter racing season, these test sessions occurred at the end of the 2000 summer racing season and coincided with the training peaks of the subjects returning from the 2000 Summer National and Summer World Championships.

Shooting performance was assessed under four different conditions in the prone and standing shooting positions (eight conditions total). The four shooting conditions consisted of: 1) Shooting with a resting heart rate prior to any exercise (INT1); 2) Decreasing to 75% of race pace (RP) 50 meters prior to entering the range (INT2); 3) Maintaining RP all the way into the range (INT3); and 4) Sprinting into the range, starting 50 meters prior to entering (INT4). All testing started with INT1 to provide a baseline shooting score. All subsequent running conditions were counterbalanced among subjects for both position and intensity to account for order effects. The same one km loop was used for all subjects during each running condition (INT2, INT3, and INT4), with changes in conditions occurring over the last 50 meters prior to entering the range. A three-minute rest was allowed for recovery between conditions. Although this three-minute recovery is toward the low end of the two to ten minute recovery range used by Hoffman et al. (1992), a longer recovery time may have resulted a cool-down effect that could potentially hinder performance on subsequent trials.

Due to the nature of the sport, biathletes tend to have highly customized rifles to maximize comfort, fit, and stability while shooting. Therefore, subjects were allowed to use their own rifles during testing, as long as they conformed to the guidelines outlined by the International Biathlon Union (IBU), the governing body of both summer and winter biathlon. Given the high level of variability associated with ballistics of any given rifle (Niinimaa, 1998), even of the same make and model, subjects were also allowed to use their preferred ammunition as long is it conformed to IBU guidelines (standard velocity, .22 cal long rifle). The non-elite subjects were provided with Marlin summer biathlon rifles and Federal Match grade ammunition since they did not possess rifles or ammunition of their own. Trigger weights were not tested, but assumed to meet the IBU requirement of at least 500 grams. Trigger weights are checked prior to all National and World level competitions and typically are not changed by the competitor once they have passed. Trigger weights of the Marlin rifles provided to the non-elite subjects well exceed the 500 gram minimum set by the IBU for safety reasons. Cuff and slings were permitted for shooting in the prone position, however they were not provided for the non-elite subjects.

Prior to testing, all subjects were allowed as much time as needed to zero their rifles, with no sight adjustments allowed once testing began. Upon completion of zero, each subject fired five rounds under resting conditions (INT1) in first the prone and then the standing position. Subjects were instructed to shoot the "tightest group possible", taking as much time as they needed. The remaining six running conditions required the subjects to shoot as they normally would in competition.

All shooting was done on paper targets and consisted of five shots per condition. Metal "knock-down" targets are utilized during biathlon competitions, providing instant feedback to the athlete as to whether a shot was hit or missed. This feedback is typically utilized by the athlete to adjust shooting cadence (how fast shots are fired). The use of paper targets for testing precluded the subjects from receiving this feedback, therefore the subjects were informed verbally after every shot whether it was a hit or miss in order for shooting cadence to be adjusted accordingly.

Since shooting performance in the sport of Summer Biathlon is based on a hit or miss system, the number of shots hit (SH) were recorded for all four conditions for both prone and standing positions. Target diameters of 40 mm for the prone and 110 mm for the standing shooting position were used to determine number of shots hit (SH). Shooting accuracy (SA) and shooting precision (SP) were also measured to better assess shooting performance. These additional dependent variables (SA and SP) increase the sensitivity for identification of an effect for prior exercise intensity on shooting performance. SA was evaluated by measuring the distance of each shot from the center of the target, while SP was determined by finding the smallest circle that encompassed all five shots. For the purpose of this study, SA and SP indicates a shooting score expressed as the distance of the shot from the center of the target (SA), or the diameter of the circle encompassing all five shots (SP). Therefore, a greater SA score results in decreased accuracy, and a greater SP score results in decreased precision.

Times were recorded for both the running and shooting components of testing. The amount of time required to run the one km loop was recorded for repeatability measures to determine if any order effects existed between conditions (i.e., to determine if running times increased as the number of conditions increased). The amount of time required to run the last 50 m was utilized to detect significant decreases in 50 m run times as intensity increased (INT2-INT4). The time component for shooting was broken down into three phases: set-up time, shooting time, and total range time. Set-up times were calculated from the time the subject stepped onto a 1.2 by 1.5 meter shooting mat, located at the shooting position, to the time the first shot was fired. Shooting time consisted of the amount of time required to fire all five shots. Total range time was calculated from the time the subject stepped onto the shooting mat until the last shot was fired. Both components of run times (one kilometer and 50 m times), as well as the three components of range time (set-up, shooting, and total range times), were recorded utilizing a stopwatch. In the event of a misfire or jammed rifle, time credit was given for the amount of time it took to clear or reload the rifle. All shooting was recorded using a video camera connected to a time-code generator. This time-code was used to calculate time credits in the event of a misfire or jammed rifle. Heart rate monitors, set to record heart rate at five-second averages, were used to collect heart rate data during all aspects of field testing. Heart rate was analyzed during set-up as the subject stepped onto the shooting mat, at the first shot, and the last shot.

The best way to account for confounding variables such as wind and cold is to collect data in a controlled condition such as an indoor shooting range. Hoffman et al. (1992) used this approach in his study and addressed the limitations of applying results from these "ideal conditions" to actual race conditions. Due to these limitations, data for the current study were collected utilizing race (field) conditions while annotating weather conditions (i.e., wind speed, temp, etc.). Attempts to minimize weather extremes included not collecting data on days with sustained winds greater than 10 mph, or temperatures colder than 0° C.

Lab Testing

On the second visit subjects reported to the Movement Science Lab at Montana State University where the maximal oxygen consumption ($\dot{V}O_{2max}$) test was administered. All subjects were allowed a familiarization period (5-10 min) on the treadmill at which time they were able to warm up until they felt ready to start the graded exercise test. During the familiarization period subjects were asked to select a treadmill speed that corresponded to their normal (comfortable) 5 km race pace (RP). This self-selected speed was used to construct a $\dot{V}O_{2max}$ protocol for each individual subject. The first stage of the $\dot{V}O_{2max}$ test involved running at 50% of the subjects self-selected RP at 0% grade for a duration of three minutes. The second stage was of same duration and grade, but the speed was increased to the subjects RP. Each subsequent stage remained at RP with a 2% increase in grade every two minutes.

Upon completion of the warm-up period the subject was connected to the gas analysis system by way of a gas collection tube running from the metabolic cart to the subject. The gas collection tube mouthpiece contained a low resistance two-way valve, which allowed ambient air to be inspired, while sending expired air to the metabolic cart for analysis. Upon initiation of the graded exercise test, the work rate was gradually increased until volitional exhaustion of the subject, while $\dot{V}O_{2max}$ was verified by satisfying two of four criteria: 1) A plateau in oxygen uptake (or failure to increase oxygen uptake by 150 mL/min) with increased workload; 2) A respiratory exchange ratio >1.15; 3) Failure of heart rate to increase with further increases in exercise intensity; 4) Rating of perceived exertion of more than 17 (6-20 scale). Such criteria for establishing $\dot{V}O_{2max}$ have been utilized by numerous sources (ACSM, 2000; Bonaduce et al., 1998). Environmental conditions in the laboratory during all $\dot{V}O_{2max}$ tests followed the guidelines outlined by in *Protocols for the Physiological Assessment of Cross-Country Skiers and Biathletes* (Martin et al., 1998). Temperature remained between 22-24° C, relative humidity was kept below 50%, and consistent airflow was provided to the subject via a fan to aid in thermoregulation. All subjects were asked to refrain from any strenuous physical activity or exercise for at least 24 hours prior to testing.

Instrumentation

All $\dot{V}O_{2max}$ tests were performed on the Trackmaster Model 48 (Vacumetrics Inc., Ventura Ca.) low-profile, oversized (belt dimensions: 1.22 x 2.44 m) treadmill. Oxygen consumption was measured by standard indirect open-circuit spirometry utilizing the

SensorMedics 2900 Metabolic Cart (SensorMedics Corporation, Yorba Linda, Ca.). Respiratory gases were sampled continuously with respiratory parameters being computed every 20 seconds. Calibration of the gas analysis system was performed prior to each test using calibrated gas mixtures (26% O_2, balance N_2, and 16% O_2, 4% CO_2, balance N_2) with which to compare ambient gas concentrations. Treadmill speed was verified using the Biddle Contact Hand Tachometer (Avo International, Blue Bell, PA) by converting number of revolutions per minute to miles per hour.

The Polar Accurex Plus™ (Polar Electro Inc., Woodbury, NY) wireless heart rate monitor, set to record heart rate at five second averages, was used to collect heart rate data during the $\dot{V}O_{2max}$ test, as well as field testing phase. A Panasonic AG-450 camcorder (Panasonic, Secaucus, NJ) was utilized to film the subjects while shooting. This allowed the investigators to adjust set-up time and shooting time in the event of a misfire or rifle jam.

Statistical analysis

A Multivariate two-factor repeated measures ANOVA was utilized to compare dependent variables (SH, SA, SP) between shooting positions (prone and standing) and exercise intensities (INT1, INT2, INT3, INT4). Differences in one km run times were tested using a single-factor repeated measures ANOVA. When statistical significance was indicated by the ANOVA analyses, individual comparisons were made using Scheffes' post-hoc analysis. An alpha level of 0.05 was chosen for establishing statistical significance for all individual tests.

CHAPTER FOUR

RESULTS

Subjects

Ten subjects participated in the study, seven elite-level competitors and three novice competitors. All elite subjects participated in the US Summer National Championships the previous year, two were members of the US Summer World Team, three were members of the US Summer National Team, and one was a three-time Winter Olympian. Although experienced runners, the shooting experience of two of the three novice subjects was limited to actual biathlon competitions. The third novice subject reportedly shot up to 300 rounds per week during the summer, but maintained only a 15% shooting average for the previous season. Due to the heterogeneous nature of the subject sample, shooting data were analyzed separately for elite-level subjects (N7), as well as for all subjects (N10). Subject characteristics are shown in Table 1, with heart rate and $\dot{V}O_{2max}$ test results shown in Table 2. Due to geographic limitations, four of the subjects were unable to returned to complete $\dot{V}O_{2max}$ testing.

Table 1. Subject Characteristics (n=10).

Subject #	Category	Gender	Age (yrs)	Height (cm)	Weight (kg)
1	Elite	M	32	180	75.0
2	Elite	M	38	179	66.8
3	Elite	M	43	187	83.6
4	Non-elite	M	22	173	60.5
5	Non-elite	M	22	170	59.6
6	Elite	M	35	189	84.1
7	Elite	M	28	188	79.5
8	Elite	F	37	173	52.0
9	Non-elite	F	41	151	51.0
10	Elite	F	21	162	56.8
Mean±SD			31.9±8.23	175.2±12.16	66.9±12.79

Table 2. Maximal heart rate (HR_{max}) and maximal oxygen uptake ($\dot{V}O_{2max}$) characteristics for all subjects. Missing data expressed as N/A (n=10).

Subject #	Category	Gender	$\dot{V}O_{2max}$ (ml/kg/min)	HR_{max} (bpm)	Predicted HR_{max} (bpm)
1	Elite	M	N/A	N/A	N/A
2	Elite	M	76.93	168	182
3	Elite	M	70.62	181	177
4	Non-elite	M	76.16	184	198
5	Non-elite	M	70.31	189	198
6	Elite	M	N/A	N/A	N/A
7	Elite	M	N/A	N/A	N/A
8	Elite	F	60.83	174	183
9	Non-elite	F	61.66	180	179
10	Elite	F	N/A	N/A	N/A
Mean±SD			69.42±6.90	179±7.4	186±9.4

Run Times

As intensity increased from INT2 to INT3 and INT4, there was a significant decrease ($p<0.001$) in 50 m run time prior to entering the range (12.52 s, 11.22 s, and 8.96 s, respectively), with no difference in one km run times (3.69±0.13 minutes, $p=0.50$). These results indicate that the independent variable (intensity) elicited the desired change in 50 m run time immediately prior to shooting, without a subsequent order effect occurring during the one km run.

Shooting Variables

Shooting scores (Means±SE) for all three measures of shooting performance are shown in Table 3. Although an increase in exercise intensity was associated with a decrease in SH for both the prone and standing position, there was no significant difference in SH as a result of position (N7: p=0.64, N10: p=0.86) or intensity (N7: p=0.10, N10: p=0.12) for either group (see Table 7 and 8 in Appendix C: ANOVA Tables for Shooting Variables). There was also no significant interaction effect for either group (N7: p=0.169, N10: p=0.162). Both groups had the same absolute decrease in the number of SH in the prone position from INT1 to INT4 (0.4 shots), but N7 averaged 0.7 shots more than N10 at any given condition. Both groups showed the same general trend in the standing position with the number of shots gradually decreasing, although not significantly, from INT1 (4.0±0.3 for N7, 3.2±0.5 for N10) to INT3 (2.0±0.3 for N7, 1.7±0.3 for N10), with a slight increase at INT4 (2.1±0.6 for N7, 1.9±0.4 for N10). Figures 1 and 2 show the number of shots hit in both shooting positions for N7 and N10, respectively.

A significant interaction effect was detected in the N7 group (see Table 9 in Appendix C: ANOVA Tables for Shooting Variables) for the SA measure of shooting performance (p=0.005). Significant differences were found in INT2, INT3, and INT4 between positions, with no difference in SA for the prone position across intensities (see Figures 3 for post-hoc comparisons). For the standing position INT3 was not significantly different from any other intensity, and INT1 and INT2 were significantly different from INT4. While a significant difference in both position (p<0.001) and