The effects of high and low carbohydrate diets on perceived energy levels of ski instructors at high altitude

Cheryl DiCarlo

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THE EFFECTS OF HIGH AND LOW CARBOHYDRATE DIETS
ON PERCEIVED ENERGY LEVELS OF SKI INSTRUCTORS
AT HIGH ALTITUDE

by

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Dean, Graduate School

Date

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ABSTRACT

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Director: Dr. Brian J. Sharkey

It was the purpose of this study to survey the effect of high and low carbohydrate diets on perceived energy levels of ski instructors at high altitude. Specifically, the study investigated the difference between the mean existing diet of instructors in comparison to the norms of the adult American diet, and the differences in perceived energy levels of instructors on a high carbohydrate diet, a low carbohydrate diet, or a normal mixed diet. A survey packet was issued to thirty full-time instructors of the Copper Mountain Ski Education Center. Nineteen completed packets met all criteria and were used for final analysis. The survey packet included five perceived energy questionnaires, four daily dietary intake forms, and suggestions for diets and alternatives.

The data was analyzed using a chi square test to establish a significant difference between three independent samples and a Z score to establish a difference between two independent proportions.

The following conclusions were supported by the study: (1) no difference occurred between the control group and the average diet of the adult American and (2) significant difference occurred in perceived energy levels among instructors on a high carbohydrate diet, a low carbohydrate diet, and a normal mixed diet.
ACKNOWLEDGEMENTS

The author wishes to express her gratitude and appreciation to the instructors of the Copper Mountain Ski Education Center and to Copper Mountain for their help and support.

The author is indebted to her husband, Michael, for his support in allowing her to continue her education, which made this thesis possible.

C.M.D.
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Chapter 1

INTRODUCTION

A vast amount of research has been done on the effects of diet on physical performance. Scientists have known for several decades that the energy necessary for muscular contraction was derived from chemical reactions within the body, and that an inadequate diet or undernutrition may impair physical performance. Unfortunately the relationship of diet to skier performance has been little known in American society.

The majority of the skiing public is not aware that diet does have an effect on physical performance, especially when the skier is abruptly exposed to high altitude. Many skiers do not realize that diet can be a major factor in adapting to acute high altitude exposure or that diet has a direct effect upon endurance and fatigue.

Skier injury statistics conclude that a majority of ski related accidents occur toward the end of the skiing day. Perhaps the knowledge that a diet has the potential to enhance skier energy levels could lead to an increase in endurance and a decrease in fatigue. Ideally diet, alone,
could decrease the incidence of skier injuries, reduce the effects of high altitude exposure, and enhance learning and enjoyment of the sport.

THE PROBLEM

The main purpose of this study was to evaluate the effects of high carbohydrate and low carbohydrate diets in relationship to a normal mixed diet on perceived energy levels of ski instructors at high altitude.

The Subproblems

The first subproblem was to determine the average existing diet of full-time instructors at the Copper Mountain Ski Education Center.

The second subproblem was to compare the mean of the existing diet of Copper Mountain instructors with the established averages for the adult American diet.

The third subproblem was to measure the perceived energy levels of the Copper Mountain instructors using an adapted General High Altitude Questionnaire (GHAQ), as cited by Evans (22).

The fourth subproblem was to establish high and low carbohydrate guidelines to be used by the experimental groups to determine dietary effects on perceived energy levels.
The Hypotheses

Hypothesis I. There will be no significant difference between the mean dietary intake of the full-time ski instructors and the established mean dietary intake of the average adult American over a five day survey period.

Hypothesis II. A change in diet will result in no significant difference in perceived energy levels of instructors at high altitude.

The Limitations

This study will be limited to full-time instructors of the Copper Mountain Ski Education Center. The study will not examine the skier population in general. High and low carbohydrate diets will not be standardized with respect to fat and protein content.

Inability to control variations in portion size and food preparation will result in approximation of dietary food intake. The inability to control the amount of sleep, alcohol, and drug intake will result in individual variations within this study.

The Definition of Terms

Full-time Ski Instructor. This is an employee of Copper Mountain, Inc., who teaches at least six days per week with staggered days off throughout the week. Teaching time is based on an average of four and one-half hours of
group lessons per day and one hour of private lesson
time per day.

Carbohydrate. This is either a simple sugar or
more complex compound such as starch which is formed by
the union of many sugar groups.

High Carbohydrate Diet. This is a diet in which
60% or more of the total daily caloric intake is composed
of some form of carbohydrates.

Low carbohydrate Diet. This is a diet in which
30% or less of the total daily caloric intake is composed
of some form of carbohydrates.

High Altitude. This represents the elevation of
Copper Mountain, Colorado which is 9,630 feet base
elevation and extends to 12,481 feet at the summit.
Chapter II

REVIEW OF
RELATED LITERATURE

Diet and Exercise

The search for a relationship between physical performance and diet is not a recent issue. The practice of consuming large quantities of meat during heavy muscular work was first recorded in Greece during the fifth century B.C. as cited by Astrand and Rodahl (5).

Protein traditionally had been the mainstay of athletes, but according to Astrand (4), protein in excess of normal daily caloric requirements was more for psychological value and taste rather than sound physiological value. Protein was found to be the least efficient energy source and was used as fuel for muscular energy only when an individual was undernourished or fasting (5, 44).

Sources of Energy

The twentieth century marked the beginning of the application of the scientific approach to the field of nutrition and physical performance. Christensen and Hansen (13) conducted one of the earliest scientific studies providing evidence that subjects placed on a high
fat diet had a marked decrease in performance capacity. Subjects became exhausted after one and one-half hours at work loads that could normally be tolerated for twice that long.

Several Swedish physiologists became involved in studies of diet and performance. Hultman (28) further demonstrated that fat and carbohydrate were mainly used for energy during exercise. Fat is the more concentrated energy source, but the conversion process of fat to energy is complicated. The conversion requires an adequate supply of oxygen in order to be utilized.

Smith (44) stated that carbohydrates are the most efficient and readily available energy source. All carbohydrates are either simple sugars or more complex compounds, such as starch, which are formed by the union of many sugar groups (9, 33). Carbohydrate is either broken down into glucose for transport via the bloodstream to the brain, muscles, and vital organs, or is converted into glycogen for storage in the muscles or liver (45).

According to Keul, et al. (33), the maximum energy yield from muscle and liver glycogen is about 700 grams. Hultman (28) found an average of seventy kilogram body weight stored about 390 grams of glycogen in the muscles and 66 grams in the liver for a total of 456 grams.

Saltin's studies (40) reiterated that aerobic processes were responsible for playing the dominate role in energy production during prolonged muscular work.
Bergstrom (?) established the use of muscle biopsy to measure glycogen levels in human muscle which contributed to the progress in analyzing dietary effects upon performance. Hermansen, Hultman, and Saltin (28) determined glycogen stores in the muscle were the limiting factor in performing prolonged strenuous work at relative high work loads. A significant decrease in muscle glycogen was noted following prolonged exercise.

The effects of a high fat and a high protein diet were compared to a normal mixed diet and to a high carbohydrate diet. Bergstrom, et al. (8) found a close correlation between the capacity for prolonged heavy exercise and the amount of glycogen stored in the muscles. Bergstrom (8) also found that muscle glycogen stores were the limiting factor in performing prolonged heavy exercise. The conclusion that glycogen content and subsequent work capacity varied appreciably was made by instituting different diets after glycogen depletion. The energy needed for muscular work was taken directly from fat and carbohydrate depots. Ahlborg, et al. (1) also concluded that a higher muscle glycogen content resulted in a longer performance time.

Glycogen Resynthesis

Hultman and Bergstrom (27) noted a marked difference between a high carbohydrate diet and a low carbohydrate
diet with respect to their ability to maintain glycogen stores in skeletal muscle. The resynthesis of glycogen is exceedingly slow on a low carbohydrate diet. Resynthesis on a high carbohydrate diet is much more rapid. Glycogen stores were also found to rise far above the normal range with the ingestion of a high carbohydrate diet. Ratliff and Lamb (39) indicate that glycogen depletion enhances resynthesis of more glycogen.

Conflicting reports have been filed regarding the resynthesis time of muscle glycogen following depletion. According to Hultman and Bergstrom (27), glycogen stores could be restored within twelve to twenty-four hours. Piehl's studies indicated muscle glycogen stores could take up to forty-six hours to be fully replenished (37). Piehl (38) later indicated that sixty percent of the total glycogen increase occurred approximately ten hours after ingestion of carbohydrates.

Hultman (28) established that the only physiological way to empty glycogen stores within the muscle was by hard exercise. Glycogen stores can decrease slowly by fasting, but one week of total starvation resulted in only a 30 to 40% decrease.

Bergstrom, et al. (8) concluded that the enhancement of glycogen synthesis is localized to muscle that has been worked and does not affect other muscle groups. Glycogen levels were depleted in an experiment involving one leg.
being exercised to exhaustion on a bicycle ergometer. Glycogen content was found to be normal in the unexercised leg.

Muscle glycogen content and work performance time was found to be dependent upon the type of diet before exercise. One experiment conducted by Bergstrom et al. (8), allowed participants to work at a fixed load for 210 minutes after a three to seven day diet of predominately carbohydrate intake. Later only 80 minutes could be tolerated at the same work load following a diet predominately of fat.

At a symposia on nutrition and fitness conducted in Sweden in 1967, Saltin and Hermansen (41) reported that the relationship between the amount of fat and carbohydrate used as fuel depended upon diet, work intensity, duration of exercise, and the fitness of the individual.

Astrand (3) stated that during rest or mild exercise the proportion of fat and carbohydrate used as fuel are relatively the same. Fat contributes in increasing amounts to energy yield as work progresses. Carbohydrate becomes more important at high intensities. Carbohydrate was not only an important oxidative substrate, as shown by Chapler and Stainsky (12), but also was the contributing energy source under anaerobic conditions. Carbohydrate also plays an increasing role in situations where the oxygen supply is limited or inadequate.

Asmussen, et al. (2) reiterated that the body's
ability to liberate energy by anaerobic processes and lactate formation was based upon the body's storage of glycogen.

**Muscle Glycogen and Fiber Type**

Costill, Sparks, Gregor, and Turner (16) established that a difference in glycogen depletion by muscle fiber type occurred. As research methods became more specific, slow twitch muscle fibers and fast twitch muscle fibers were found to differ with respect to glycogen concentrations. Glycogen depletion was found to be less in fast twitch fibers than in slow twitch fibers after a mixed or carbohydrate diet. Slow twitch fibers were depleted of glycogen at work intensities of sixty to eighty percent of maximum oxygen uptake. Fast twitch fibers were not depleted until an individual exercised to exhaustion (17, 18).

Costill, et al. (17) found that subjects who exercised to near exhaustion on successive days needed dietary allowances including a carbohydrate rich diet to continue to function at that level.
DIET AND ALTITUDE

The energy cost of muscular work must be defrayed primarily through oxidative processes. According to Keul, Doll, and Keppler (33), the individual experiences a reduced ability to extract oxygen during hypoxic conditions. The result of hypoxia is a reduction of man's ability to perform work.

Frisancho (23) studied subjects exposed rapidly to high altitude and found newcomers to altitude experienced a reduction in aerobic capacity of thirteen to twenty-two percent. Oxygen has about thirty-five percent less pressure at 3000M (11,840 feet) than at sea level. Horvath (26) reported that maximum oxygen uptake is decreased by 3.2% for every 1000 feet in elevation. An acclimatized man will experience only a 2% decrease.

The blood is less saturated with oxygen at high altitude; therefore, not as much oxygen is transported to the tissues. Hurtado (29) found the greater the intensity of exercise, the less the oxygen saturation of arterial blood occurred.

Muscle glycogen is severely exhausted as an immediate source for energy yield under hypoxic conditions. Consalazio, Matoush, Johnson, Krzywicki, Davis, and Issac (14) studied mountain climbers and orienteers during high altitude exposure. A marked craving for sweets and sugar was noted. Prior to World War II a physiological advantage was noted in feeding a carbohydrate
Carbohydrate Metabolism and Hypoxia

Carbohydrate metabolism is of particular importance under conditions of hypoxia. Hansen, Hartley, and Hogan (24) concluded that feeding of a carbohydrate rich diet is a feasible way to increase ventilation and improve oxygenation when ambient air is decreased. A carbohydrate rich diet increased carbon dioxide production which in turn stimulated the respiratory system and raised the oxygen content in the lungs during conditions of low oxygen atmosphere (as cited in Science News, 42).

Hansen and associates also noted the feeding of a high carbohydrate diet was desirable in early acclimitization or in anorexia. This loss of appetite, therefore, led to a caloric deficit as found by Consolazio, et al. (15).

A high carbohydrate diet was beneficial in increasing work capacity, decreasing acute mountain sickness symptoms and its severity, and increasing mental efficiency. Johnson, Consolazio, Krzywicki, and Daws (31) found that men on high carbohydrate diets fared better when exposed to acute altitude than those on a normal diet or a diet high in protein. Hansen, et al. (24) determined that natives residing in extreme high altitude areas naturally
tend to incorporate large amounts of carbohydrates in their diet. Andean natives consume a diet of 79% to 89% carbohydrates.

DIET AND ALPINE SKIING

The aerobic demands in recreational and competitive downhill skiing are great. A linear relationship has been established by Karlsson, Eriksson, Forsberg, Kallberg, and Tesch (32) between heart rate and oxygen uptake during downhill skiing. As oxygen demand increases, the heart beats faster. ECG recordings during two hours of recreational alpine skiing on rather easy slopes yielded heart rate of 160 - 170 beats per minute. Eriksson, et al. (20) found that this was only five to twenty beats per minute below maximum heart rates. Karlsson, et al. (32) also monitored the aerobic demands of competitive alpine skiers and recorded heart rates approaching maximum.

Glycogen Utilization and Skiing

Quantitative measurements of glycogen content, done by Eriksson, et al. (20) in the thigh muscles of skiers, showed after an entire day of skiing, muscle glycogen in experienced skiers declined by 35 - 40 mmoles/kg of wet muscle tissue. This was true for skiing both short and long slopes. Beginning skiers showed a reduction
of 25 - 30 mmoles/kg of wet muscle tissue.

During a week of skiing, total glycogen consumption was calculated by determining the glycogen content in tissues before and after exercise. Morning glycogen levels showed a decline from 70 - 80 mmoles/kg wet muscle tissue on the first day to around 50 mmoles/kg on the fifth day. 70 - 80 mmoles/kg represent values similar to what is normally found in the thigh muscle after a normal mixed diet; whereas, 50 mmoles/kg is below normal level of muscle glycogen storage.

Afternoon levels following exercise also declined far below normal. When subjects were advised to consume a high carbohydrate diet on the third day of testing, those participants involved had glycogen levels far above normal when measured the following day.

When testing competitive skiers at a training camp, Karlsson, et al (32) found glycogen stores gradually declined day by day. They concluded that a relatively high concentration of muscle glycogen was essential to the maintenance of good muscular function. Karlsson also concluded that there is every reason to believe that the injuries which often occurred at the end of a day of training were frequently linked to muscle fatigue caused by a glycogen deficiency. This was also applicable to the active recreational skier. Thus according to Karlsson, the high incidence of injury at the close of
the skiing day could be related to glycogen deficiency.

PERCEIVED EXERTION

Man can perceive small differences in work intensities. A healthy adult is capable of discerning differences between work loads (Skinner, Hustler, and Buskirk, 43). Morgan (35) agreed with this capacity of man, but added that the capacity to perceive small differences in work intensity did not apply to depressed, neurotic, or anxious people, as they had difficulty in assessing the work situation appropriately.

Research by Noble, Metz, and Cafarelli (36) concluded that responses to exertion or perceived energy levels are made from sensations which result from physiological processes. Man does not directly attend to changes in the physiological processes, per se, but to the externalization of these processes, such as increased ventilation, other respiratory responses, and skin temperature.

Ekblom and Goldberg (21) evaluated individual's perceived exertion on two levels. The first is a local level in which the individual actually feels strain in the muscles. The second level is a central factor such as tachycardia, tachypnea, or even dyspnea.

A mood symptom questionnaire, as cited by Carson, et al. (11), was developed to record subject symptomology for persons subjected to acute high altitude exposure.
The questionnaire allowed subjects to rate the severity of their reactions on a scale from one to five. Later testing, by Evans (22), found the questionnaire to be reliable and valid based upon perceived symptomology as opposed to actual physiological changes.

SUMMARY OF REVIEW

The majority of researchers conclude that carbohydrates are the most efficient and readily available energy source for vigorous work. Most studies are in agreement that glycogen stores in the muscles are one of the biggest limiting factors in performing prolonged strenuous work at relative high work loads.

A marked difference was found between a high carbohydrate diet and a low carbohydrate diet with respect to the ability to maintain glycogen stores in skeletal muscle. Resynthesis of glycogen was proven to be exceedingly slow on a low carbohydrate diet; whereas, resynthesis was extremely rapid on a high carbohydrate diet.

Researchers found carbohydrate metabolism to be of particular importance under conditions of hypoxia. Feeding of a high carbohydrate diet was desirable in early acclimitization to altitude to increase work capacity, decrease acute mountain sickness symptoms and its severity, and increase mental efficiency.

Data also revealed that glycogen stores gradually decline with successive days of skiing. There was some
indication that the incidence of skier injury levels and glycogen deficiency could be related.

Finally, research indicates that subjects are capable of perceiving differences in symptomology and work loads based upon external and internal changes.
Chapter III

METHOD AND PROCEDURE

This research was designed to study the effects of high carbohydrate and low carbohydrate diets, in relationship to a normal mixed diet, on perceived energy levels of ski instructors at high altitude.

THE SUBJECTS

Thirty full-time instructors of the Copper Mountain Ski Education Center volunteered to participate in the study. Participants included nineteen men and eleven women ranging in age from twenty-three to fifty-five. The mean age was 30.1 years.

SURVEY PROCEDURES

The thirty participants were assigned to one of three groups by a random draw. Each subject received a survey packet and oral instruction as to procedures, depending upon group assignment.

Each survey packet contained a liability release form (Appendix A), five perceived energy questionnaires (Appendix C), four daily dietary intake forms (Appendix B), and sample diets depending upon group assignment.
All thirty subjects were allowed to choose when to begin the experiment to avoid overlapping with days off or days not skied. Subjects were instructed to fill out the first perceived energy questionnaire on the same day the first dietary intake form was completed.

Participants were expected to either be skiing or teaching on the days in which the survey forms were completed. Instructors were to fill out the perceived energy questionnaire immediately after ski school check-out time in the afternoon. The subjects were to record their immediate reaction as to how they perceived themselves at that very moment and not try to analyze the questionnaire too closely.

SURVEY GROUPS

Group One - Control

Group one was made up of ten subjects chosen by a random draw from the initial group of thirty volunteers. They were designated to be the control group and were to consume their normal diet (NMD). All subjects were issued the basic survey packet with instructions to record everything consumed, including beverages, for four consecutive days. They were to simultaneously fill out the five consecutive perceived energy questionnaires. All subjects in the control group were advised to eat and
drink in as normal a pattern as possible.

**Group Two - High Carbohydrate Intake**

Ten subjects were assigned by a random draw to group two, known as the high carbohydrate diet group (HCD). Group two subjects received the basic survey packet plus a sample high carbohydrate diet with suggestions for alternatives (Appendix D). The HCD group was instructed to consume at least sixty percent of their total dietary intake in the form of carbohydrates.

**Group Three - Low Carbohydrate Intake**

The final ten subjects were assigned to the low carbohydrate intake group (LCD). They received the same basic survey packet plus sample low carbohydrate diets with suggestions for alternatives (Appendix E). This group was instructed to consume no more than thirty percent of their daily caloric intake in the form of carbohydrates.

**STATISTICAL PROCEDURES**

After all the data was collected, the daily dietary intake forms were analyzed regarding content based upon computations as set forth by Deutsch (19).

Data to test the Null Hypothesis I stating that no difference would occur between the control group's diet and the established averages for the adult American's diet,
was analyzed using Z Scores to establish the significant differences between two independent proportions.

Those subjects meeting the established criteria for carbohydrate intake were used for further analysis of Hypothesis II which states no difference would occur in perceived energy levels of ski instructors ingesting a high carbohydrate diet, a low carbohydrate diet, or a normal mixed diet over a five day survey period.

Data to test the Null Hypothesis II was analyzed using Chi Square tests to determine significant differences between samples.

Formulas for computation are found in Appendix F.
Chapter IV
ANALYSIS OF DATA

Survey packets were administered to thirty instructors of the Copper Mountain Ski Education Center. Data was collected and analysis was done based upon information obtained from the dietary intake forms and the perceived energy questionnaires.

Twenty-four completed survey packets were returned. Dietary intake forms for actual diet consumed by all subjects were analyzed to establish whether the criteria (ie. 60% or greater CHO intake for group two or 30% or less CHO intake for group three) for group assignment had been followed and met. Two subjects, assigned to group two and group three respectively, had switched diets with each other due to individual dietary preferences. Neither individual met the criteria and were not used in final analysis.

Nineteen subjects met all established criteria and were used for further analysis. The results of the content analysis of the daily dietary intake forms are shown in Table I.

Eight control group survey packets were returned and all met established criteria. Only four of the eight high carbohydrate survey packets returned met the sixty
<table>
<thead>
<tr>
<th></th>
<th>Group One (Control)</th>
<th>Group Two (High CHO)</th>
<th>Group Three (Low CHO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% CHO</td>
<td>Fat</td>
<td>Protein</td>
<td>% CHO</td>
</tr>
<tr>
<td>JC 35</td>
<td>48</td>
<td>17</td>
<td>RA 52</td>
</tr>
<tr>
<td>TD 29</td>
<td>38</td>
<td>33</td>
<td>SC 65</td>
</tr>
<tr>
<td>EJ 56</td>
<td>37</td>
<td>7</td>
<td>SG 62</td>
</tr>
<tr>
<td>DM 41</td>
<td>45</td>
<td>14</td>
<td>JJ 60</td>
</tr>
<tr>
<td>GM 45</td>
<td>35</td>
<td>20</td>
<td>JJ 54</td>
</tr>
<tr>
<td>MP 29</td>
<td>60</td>
<td>11</td>
<td>GS 60</td>
</tr>
<tr>
<td>KS 35</td>
<td>33</td>
<td>30</td>
<td>TS 50</td>
</tr>
<tr>
<td>BS 37</td>
<td>39</td>
<td>24</td>
<td>PS 55</td>
</tr>
</tbody>
</table>

* % representations are approximate as exact caloric intake as to portion and serving size and individual food preparation were not measured in this study.
percent carbohydrate intake level. Seven of the eight low carbohydrate intake survey packets could be used for final statistical analysis.

Testing of Null Hypothesis I

The control group was compared with the adult American norms as set forth by a U.S. Senate Select Committee on Nutrition and Human Needs. According to Brody (10), the average adult American consumes a daily average of 42% fat, 12% protein, and 46% carbohydrates. The daily dietary intake mean of the control group was 42% fat, 19% protein, and 38% carbohydrates.

A Z score to establish the significant differences between two independent proportions was used to determine whether to accept or reject the Null Hypothesis I that no difference would occur between the control group and the average American diet. The results are shown in Table II.

According to the Z scores no significant difference does exist between the norms for the American population and the dietary intake of the control group. The Null Hypothesis I was then retained on the basis of no significant difference.

Testing of Null Hypothesis II

All answers on the perceived energy level questionnaire were assigned a corresponding numerical value from one to five. These answers were based upon the subject's reaction
TABLE II

DIFFERENCES BETWEEN GROUP ONE AND AVERAGE AMERICAN ADULT DIET

<table>
<thead>
<tr>
<th></th>
<th>% CHO</th>
<th>Protein</th>
<th>Fat</th>
</tr>
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<tbody>
<tr>
<td>Average American Diet</td>
<td>46%</td>
<td>12%</td>
<td>42%</td>
</tr>
<tr>
<td>Group One Mean</td>
<td>38%</td>
<td>20%</td>
<td>42%</td>
</tr>
<tr>
<td>Z Score</td>
<td>.4653</td>
<td>.5357</td>
<td>.0075</td>
</tr>
</tbody>
</table>

p = .05
to his present energy level at the time of testing.

Each score was tabulated to find a daily median and a five day cumulative median for each subject, as well as for each group respectively. The results are shown in Table III for the control group, Table IV for the high carbohydrate intake group, and Table V for the low carbohydrate intake group.

Figure I graphically represents the daily medians for the control group, the high carbohydrate group, and the low carbohydrate intake group.

FIGURE I

PERCEIVED ENERGY
TABULATION BETWEEN GROUPS

<table>
<thead>
<tr>
<th>Perceived Energy</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>high</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>low</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

C = control
H = high carbohydrate diet
L = low carbohydrate diet

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### TABLE III

**PERCEIVED ENERGY QUESTIONNAIRE TABULATION FOR THE CONTROL GROUP**

<table>
<thead>
<tr>
<th></th>
<th>day 1</th>
<th>day 2</th>
<th>day 3</th>
<th>day 4</th>
<th>day 5</th>
<th>cumulative</th>
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<tr>
<td>JC</td>
<td>3.4</td>
<td>2.9</td>
<td>2.8</td>
<td>2.6</td>
<td>2.2</td>
<td>2.78</td>
</tr>
<tr>
<td>TD</td>
<td>4.2</td>
<td>3.8</td>
<td>4.2</td>
<td>3.9</td>
<td>4.2</td>
<td>4.06</td>
</tr>
<tr>
<td>EJ</td>
<td>2.9</td>
<td>2.8</td>
<td>4.1</td>
<td>3.0</td>
<td>2.9</td>
<td>3.14</td>
</tr>
<tr>
<td>DM</td>
<td>3.2</td>
<td>3.0</td>
<td>2.5</td>
<td>3.2</td>
<td>3.3</td>
<td>3.04</td>
</tr>
<tr>
<td>GM</td>
<td>3.7</td>
<td>4.2</td>
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<td>3.1</td>
<td>2.9</td>
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</tbody>
</table>

**Median**

3.45   2.95   3.05   3.25   3.45   3.17
TABLE IV
PERCEIVED ENERGY QUESTIONNAIRE
TABULATION
FOR THE HIGH CARBOHYDRATE GROUP

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
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<th>Day 5</th>
<th>Cumulative</th>
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<td>3.83</td>
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TABLE V

PERCEIVED ENERGY QUESTIONNAIRE

TABULATION

LOW CARBOHYDRATE GROUP

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<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Cumulative</th>
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</thead>
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<tr>
<td>RK</td>
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<td>3.4</td>
<td>3.5</td>
<td>3.1</td>
<td>3.22</td>
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</table>
The Null Hypothesis II, which states that no difference between perceived energy levels will occur when subjects are measured on a HCD, a LCD, or a NMD over a five day survey period, was analyzed using a chi square test to establish significant differences between independent samples.

Chi square test results are shown in Table VI. No significant difference was found between any of the three groups on the first and second day of the survey. A significant difference ($p = .05$) did occur on day three between the HCD group and the LCD group. Significant difference also occurred between these groups on the fifth day.

No significant difference was found between the NMD and the HCD groups. Nor were any significant differences found on any of the days between the NMD group and the LCD group.

The cumulative scores showed no significant differences between the three groups.

The Null Hypothesis II was rejected on the basis that significant difference did occur between perceived energy levels of the HCD group and the LCD group on the third and fifth days.
TABLE VI

COMPARISONS OF DIFFERENCES
BETWEEN GROUPS

\( p = .05 \) *

<p>| | |</p>
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<thead>
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<th></th>
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<tbody>
<tr>
<td>day 1</td>
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<tr>
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<td>day 4</td>
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<tr>
<td>day 5</td>
<td>8.8969*</td>
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</tbody>
</table>

CHI SQUARE COMPARISONS
BETWEEN ALL GROUPS

<p>| | |</p>
<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>day three</td>
<td></td>
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<td>HCD/LCD</td>
<td>5.2288*</td>
</tr>
<tr>
<td>HCD/NMD</td>
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<tr>
<td>LCD/NMD</td>
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<tr>
<td>day five</td>
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Chapter V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

This study was conducted to survey the difference between perceived energy levels of ski instructors at high altitude in relationship to a high carbohydrate diet, a low carbohydrate diet, and a normal mixed diet. The difference between the control group, on a normal mixed diet and the established norms for the adult American diet were also surveyed.

Thirty full-time ski instructors participated in the survey. Ten instructors were assigned to each of three groups. Group one was designated the control group. Group two was the high carbohydrate intake group, and group three was designated the low carbohydrate intake group.

Twenty-four completed survey packets were returned. Nineteen of the twenty-four packets met all criteria and were used for final analysis of data.

There were two main objectives in this study. The first objective was to establish whether the existing diet of ski instructors at the Copper Mountain Ski Education Center, as measured by the control group, were
consistent with the established dietary averages of the adult American. The second objective was to determine if differences in high and low carbohydrate intake over a five day survey period could result in changes in perceived energy levels.

Data was analyzed using Z scores to determine differences between the control group and the adult American population. Chi square tests were used to establish differences in perceived energy levels between instructors on a high carbohydrate diet, a low carbohydrate diet, or a normal mixed diet. The level of significance was accepted at $p = .05$.

The analysis of data yielded the following findings:

1. No significant difference was found between the daily dietary intake of the control group on a NMD when compared to the norms for the American population.

2. No difference was found in perceived energy levels between diets on either the first or second day of the survey.

3. Significant difference did occur on the third day between perceived energy levels of instructors on a HCD when compared to those on the LCD. Difference was also found on the fifth day between these two groups, with the high carbohydrate intake group presenting higher perceived energy levels.
4. No significant differences were found between instructors on a HCD and those on a NMD. No differences were found between the control group on a NMD and the LCD group.

CONCLUSIONS

This study was undertaken to determine whether differences in perceived energy levels of ski instructors could be distinguished between subjects on a HCD, a LCD, or a NMD and whether the diet of the average ski instructor at the Copper Mountain Ski Education Center was consistent with the average American Adult's diet. The results support the conclusions that the diet of the Copper Mountain instructor is consistent with that of the American population. Secondly, differences in perceived energy levels can occur within a five day period when subjects are subjected to different amounts of carbohydrate ingestion.

The results of this study show that no significant difference occurred among diets on the first or second day. Significant differences did occur on the third and fifth days between the HCD group and the LCD group. These results are consistent with the earlier findings of Hultman, Costill, Eriksson, and Karlsson (28, 17, 20, 32). The HCD group had higher perceived energy scores on the third and fifth days than either the low carbohydrate intake group.
or the control group. No significant differences occurred between the control group and the LCD subjects or between the HCD subjects and the control group on a NMD.

The Null Hypothesis I was retained on the basis that no differences were found between the protein, fat, and carbohydrate intake of the control group when compared to the average American adult's diet. The Null Hypothesis II was rejected when significant differences were found between the HCD group and the LCD group.

RECOMMENDATIONS

This investigation has compiled data that suggest the diet of the full-time ski instructor at Copper Mountain was consistent with the average American diet. The investigation also suggests that a dietary change high in carbohydrates was beneficial in increasing perceived energy levels on a five day testing period.

Despite significant results, obvious limitations occurred in this study. Inability to control precise serving size and individual food preparation resulted in approximations regarding caloric intake. Extraneous variables including amount of sleep, alcohol, and drug intake were not measured.

Recommendations for Future Research

The present study has compiled data which may aid in understanding the role of diet on skier energy levels.
Further research is recommended in order for this information to be applicable to the skier population in general. Further research should include the following:

1. Conduct the survey over a longer period of time to eliminate the possibility of a placebo effect.

2. Use the same subjects on both a HCD and a LCD to eliminate the effects of individual variations including sleep, alcohol, and drug intake.

3. Maintain a log of vertical feet of skiing per day and whether skiing was done in a teaching situation or a free skiing situation.

4. Survey the skier population, in general, to establish whether diet can result in decreased fatigue and increased enjoyment of the sport.

5. Study the skier population in relationship to diet to measure whether a change in diet can decrease the incidence of skier injury.
SELECTED BIBLIOGRAPHY
BIBLIOGRAPHY


APPENDIX A

VOLUNTEER FORM
VOLUNTEER FORM

THE EFFECTS OF HIGH AND LOW CARBOHYDRATE DIETS
ON PERCEIVED ENERGY LEVELS OF SKI INSTRUCTORS
AT HIGH ALTITUDE

I hereby freely volunteer to act as a subject in a scientific investigation as an authorized part of the educational and research program of the University of Montana and the Copper Mountain Ski Education Center. I acknowledge that I have read and concur in the procedures and objectives of this investigation as summarized on this sheet.

I certify that to the best of my knowledge and belief, I have no physical or mental illness or weakness that would increase the risk to me of participation in this investigation.

The investigation involves the analysis of different diets on the perceived energy level of full-time ski instructors. Volunteers will be randomly divided into three groups. One group will remain on their normal diet and will fill out a five day series of questionnaires. One group will be asked to consume a carbohydrate rich diet for four consecutive days and the last group will consume a carbohydrate low diet for the four day period. Changes in diet were not designed to affect weight loss or gain.

If you decide to volunteer please sign this sheet indicating your willingness to comply with the provisions of the investigation and your willingness to assume personal risks of participation.

Date_____________________

Age_____________________

Signature of Subject_________
DIETARY INTAKE RECORD

Please list everything consumed daily including beverages. List quantity or serving size if known.

Name

Date

BREAKFAST

LUNCH

SNACKS

DINNER

SNACKS
APPENDIX C

PERCEIVED ENERGY QUESTIONNAIRE
**PERCEIVED ENERGY QUESTIONNAIRE**

Fill out as soon as possible after ski school check-out or skiing. Put a circle around the phrase which best describes how you feel right at this moment. Put down what first comes to mind. Do not try to analyze too closely.

1. very lively  | a little lively  | about average  | less lively  | not lively
               | liveliness      | than usual     | at all       |
2. not tired  | less tired than  | about average  | a little tired | very tired
      at all    | usual           | tiredness      |             |
3. not irritable  | less irritable  | about average  | a little     | very
       at all    | than usual      | irritability   | irritable    |
4. no headache  | a little        | some headache  | bad headache  | severe
      at all    | headache        |               | headache     |
5. very active  | a little active | about usual    | less active  | not active
               | activity        | than usual     | at all       |
6. not lazy  | less lazy than  | about usual    | less active  | not active
      usual     | laziness        | than usual     | at all       |
7. very energetic  | a little energetic | about usual | less energy  | not energetic
               | energetic       | energy         | than usual   | at all       |
8. very refreshed  | a little refreshed | about usual | less refreshed | not refreshed
               | refreshed       | refreshed      | than usual   | at all       |
9. very comfortable  | a little comfortable | about usual | less comfort  | not comfortable
               | comfortable     | comfort        | than usual   | at all       |
10. not hungry  | less hungry     | about usual    | a little     | very hungry
      than usual | hungriness      | hungry         | }
APPENDIX D

HIGH CARBOHYDRATE SAMPLE DIET

AND ALTERNATIVES
## HIGH CARBOHYDRATE SAMPLE DIET AND ALTERNATIVES

You will be on a high carbohydrate diet for four consecutive days. Listed below are sample high carbohydrate diets. These are only for reference and need not be followed explicitly. You are free to choose from the alternative list that follows. Try to stay within your normal caloric intake but substitute carbohydrate rich foods for as much of your caloric intake as possible.

<table>
<thead>
<tr>
<th>BREAKFAST</th>
<th>LUNCH</th>
<th>DINNER</th>
<th>SNACKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEREAL</td>
<td>jelly sandwich</td>
<td>Spaghetti</td>
<td>raisins or</td>
</tr>
<tr>
<td>SKIM OR 2% milk</td>
<td>fruit (apple)</td>
<td>Salad</td>
<td>fruit or</td>
</tr>
<tr>
<td>toast and jam</td>
<td>soda or fruit</td>
<td>cake or pie</td>
<td>dessert</td>
</tr>
<tr>
<td>juice</td>
<td>drink</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>chocolate bar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| french toast or    | hamburger        | chicken         | same as above   |
| pancakes           | fruit            |anghai           |                 |
| juice              | soda or fruit    | mashed potatoes |                 |
|                    | drink            | vegetables      |                 |
|                    |                   | fruit salad     |                 |

*coffee, tea, or water may be consumed with any meal or anytime.

**SUGGESTED ALTERNATIVES**: whole grain breads and cereals, spaghetti, lasagna, pasta, Mexican food, Italian food, pie, cake, waffles, pancakes, cookies, popcorn, potatoes, rolls, jelly, all vegetables, fresh and dried fruit, wheat, rice, corn, fruit juices, soft drinks, skim or 2% milk, beer instead of mixed drinks, lettuce, cabbage, and if meat desired - poultry and fish (preferably only once).

**FOODS TO AVOID**: red meat (beef and pork), whole milk cheese, ice cream, bacon, eggs, excess butter, margarine, salad oil, peanut butter, potato chips, and french fries. Avoid most fried foods.
APPENDIX E

LOW CARBOHYDRATE SAMPLE DIET

AND ALTERNATIVES
LOW CARBOHYDRATE SAMPLE DIET
AND ALTERNATIVES

You will be on a low carbohydrate diet for four consecutive days. Listed below are sample low carbohydrate diets. These are only for reference and need not be followed explicitly. You are free to choose from the alternative list that follows. Try to stay within your normal caloric intake but substitute foods that are low in carbohydrate for as much of your caloric intake as possible.

BREAKFAST  LUNCH  DINNER  SNACKS
two eggs  hard boiled  steak  yogurt or
bacon  eggs  salad  ice cream
milk  yogurt  french fries  milk

yogurt  grilled cheese  beef or pork  cheese or
"Al's doughnut"  french fries  salad  above
milk  milk  fried potatoes

*coffee, tea, or water may be consumed with any meal or anytime.

SUGGESTED ALTERNATIVES: bacon, eggs, salad, salad dressing, cheese, dairy products, whole milk, peanuts, potato chips, ice cream, as much beef and pork as desired. Mixed drinks that do not include pop should be substituted for beer.

FOODS TO AVOID: breads, cereals, pancakes, waffles, wheat, rice, corn, excess fruits and vegetables, beer pasta, spaghetti, lasagna, and most desserts in excess such as pie, cake, and cookies.
APPENDIX F

FORMULAS FOR COMPUTATION
FORMULAS FOR COMPUTATION

Chi Square test to measure a significant difference between independent samples:

\[ X^2 = \frac{N(AD - BC)^2}{(A + B)(C + D)(A + C)(B + D)} \]

degree of freedom = (Rows - 1) (Columns - 1)

Z score to measure a significant difference between two independent proportions:

\[ Z = \frac{P_1 - P_2}{\sqrt{SP_1 - P_2}} \]

P = proportion
S = standard error of proportion

\[ SP_1 - P_2 = \sqrt{pq x \left(\frac{1}{N} x \frac{1}{N}\right)} \]