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Effects of carbohydrate beverage ingestion on indicators of atheletic performance in female varsity lacrosse players

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EFFECTS OF CARBOHYDRATE BEVERAGE INGESTION ON INDICATORS OF ATHLETIC PERFORMANCE IN FEMALE VARSITY LACROSSE PLAYERS

by

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An Abstract

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ABSTRACT

Nine female Division III college varsity lacrosse players were studied in controlled laboratory testing while four of the same nine plus an additional four subjects participated in a rigorous field experiment (N=8). In a randomized, double-blind design, subjects ingested a carbohydrate (CHO) or placebo beverage (6 ml/kg body weight 15 min before exercise and 3 ml/kg body weight during and after exercise) every 20 min while exercising alternately on a cycle and upper body ergometer for 140 min. Each subject acted as her own control.

Shooting Drill A (goal points while being timed) and Shooting Drill B (goal points for accuracy) were used to determine skill performance. Dependent t-tests did not reveal a significant difference at the .05 level and mean scores for both drills were marginally greater for placebo than CHO (A: M = 8.7 vs. 7.7; and B: M = 12.1 vs. 11.4 pts). However, mean scores for both drills in the field setting were greater for CHO than placebo (A: M = 7.6 vs 6.6; and B: M = 6.9 vs 3.6) although, once again the dependent t-tests revealed no significant differences.

A modified Wingate Anaerobic Test (WAT) was used

to determine anaerobic power, specifically average power (AP) and peak power (PP). MANOVA showed scores for PP were significantly higher at the .05 level when the CHO beverage was ingested than when the placebo was ingested (PP: 294.3 vs 226.1 watts).

Repeated measures ANOVAs (2 X 4, Condition X Time) were used to determine the effects of CHO beverage consumption on lactate and glucose levels in the blood. Lactate levels were significantly higher ($p < .05$) across all times when CHO was ingested than when the placebo was ingested. A significant interaction followed by dependent t-tests at each time revealed that glucose levels were significantly greater ($p < .05$) at 60 min when the CHO was ingested than when the placebo was ingested. In addition, a trend toward significance occurred at 140 min ($p = .058$) with glucose levels being higher during CHO than placebo conditions.

Reaction time (RT) and speed of movement (SMVT) scores were based on subject's ability to respond to a visual stimulus. Doubly MANOVA showed that the mean RT and SMVT scores for CHO treatment were very similar to that of the placebo (RT: $M = 214.8$ vs. 217.3; and SMVT: $M = 365.4$ vs. 367.9 ms) and not significantly different.

In conclusion, the CHO beverage improved power output (i.e., AP and PP) and metabolic profile. These results may indicate the potential for enhanced athletic performance in female lacrosse players, however, the ingested CHO beverage did not seem to enhance the performance of sport specific skills.

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A Thesis Presented to the Faculty of
the School of Health Sciences and
Human Performance
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Requirements for the Degree
Master of Science

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by
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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Sciences and Human Performance at Ithaca College has been approved.

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Date: May 5, 1995

DEDICATION

This thesis is dedicated to my father, the late John Robert Wood, who said to me: "Kris, you can do anything you put your mind to." I think of you every time I do something I think you'd be proud of.

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Chapter 1

INTRODUCTION

A premise previously established is that the ingestion of commercially available carbohydrate (CHO) beverages can aid in endurance performance (Mitchell, Costill, Houmard, Fink, Pascoe, and Pearson, 1989). It is believed that through the intake of a CHO beverage, thermoregulation and circulatory function are better maintained. The exact reason for this phenomenon is unclear though the sparing of glycogen and/or the elevation of blood glucose may lead to improved endurance. However, these beverages are often used by athletes whose performance is dependent not only upon endurance but also motor skill, reaction time (RT), and power production. It is logical to assume that muscles with better energy reserves and a central nervous system with more access to fuel (i.e., glucose) will perform more precisely, however, these assumptions have never been empirically tested. Accordingly, the purpose of the present study is to examine the effect of a commercially available CHO beverage upon indicators of athletic skill. This will be accomplished by creating conditions that simulate the physiological fatigue experienced near the end of an athletic contest in both laboratory and field settings.

Statement of Problem

The purposes of the study were to determine the effects of a commercially available CHO beverage or placebo on (a) skill performance, (b) power output (peak power (PP) and average power (AP), (c) blood profile (lactate and glucose) and, (d) RT/speed of movement (SMVT).

Scope of Problem

The effects of a commercially available CHO beverage on skill performance, specifically, goal scoring in the sport of lacrosse was investigated. In addition, several dependent variables that could affect lacrosse performance were also measured in the laboratory (e.g., RT, SMVT, PP, and AP). Subjects for the study were healthy female volunteers from a women's Division III varsity lacrosse team and ranged in age from 18 to 22 years old. Nine individuals were tested in the laboratory where the purpose was to simulate, under controlled conditions, the physiological fatigue that occurs in a typical lacrosse contest. Each of the nine acted as her own control in a repeated measures design. During 140 min of alternating exercise on a cycle and upper body ergometer (UBE), subjects periodically consumed either a 6% CHO beverage or an equal volume of a flavored placebo. Blood samples were taken at 0, 60, 100, and 140 min for determination of blood lactate (HLA) and glucose (G) levels. Next, the subject performed a modified Wingate Anaerobic Test (WAT) in which she had to pedal a cycle as fast as possible for 30 s. The purpose of this was to measure AP and PP. Two shooting drills were then performed. The last performance measure included a RT test in which the subject responded to a visual cue. The time to react to the stimulus as well as the SMVT were recorded.

Eight individuals were tested in a field study, of whom four were new subjects and four had participated in the laboratory test. Each participant in the field study acted as her own control in a repeated measures design. The field study consisted of a strenuous varsity lacrosse practice, during which the subjects ingested either the 6% CHO beverage or flavored placebo every 20 min. Following the practice, the subjects performed two shooting drills as a measure of performance ability.

Hypotheses of Study

The following null hypotheses concerning performance measures were identified:

Ho_1: There will be no significant differences between the shooting scores from the CHO and placebo conditions in either the field or laboratory trials.

Ho_2: There will be no significant differences between the laboratory power scores (i.e., AP and PP) from the CHO and placebo conditions.

Ho_3: There will be no significant differences between the laboratory scores of the RT and SMVT tests from the CHO and placebo conditions.

Ho_4: There will be no significant differences between the laboratory scores of the G and HLA tests from the CHO and placebo conditions.

Definition of Terms

The following terms that were used in this study are herein defined:

1. Anaerobic capacity: The ability to persist at the maintenance or repetition of strenuous muscular contractions that rely substantially upon anaerobic mechanisms of energy supply (Lamb, 1984).

2. Anaerobic power: The maximal rate at which energy can be produced or work can be performed without a significant contribution of aerobic energy production (Lamb, 1984).

3. Average power: The mean work produced per unit time (Powers & Howley, 1990). This is estimated from the WAT.

4. Peak power: The maximum work produced per unit time. This is estimated from the WAT.

5. Wingate Anaerobic Test: A 30 s cycling test to exhaustion that determines AP and PP.

6. Gastric emptying: The ability of a fluid to be rapidly emptied from the stomach into the small intestine and then across the intestinal membrane into the bloodstream (Coleman, 1988).

7. Osmolality: A measure of the total concentration of a solution; the number of moles of solute per kilogram of solvent (Dorland's Illustrated Medical Dictionary, 1988).

Assumptions of Study

The following assumptions of the study were made:

1. Subjects clearly understood all the requirements necessary for all performance tests, and

performed to the best of their ability during each testing session.

2. Sufficient recovery was allowed between repeated testing sessions to permit equivalent glycogen restoration for all subjects.

3. Subjects did not change their exercise habits throughout the course of the study.

4. Subjects did not change their dietary habits throughout the course of the study.

5. The baseline tests were a reasonable measure of 80% of maximal capacity.

6. The WAT is a representative measure of anaerobic power and anaerobic capacity, and the techniques employed in this study yielded accurate AP and PP scores.

Delimitations of Study

The following were the delimitations of the study:

1. Only 14 female subjects, 18 to 22 years of age, were tested.

2. The study was conducted in both laboratory and field settings using specific exercise and practice protocols.

3. Only collegiate varsity lacrosse players were used as subjects.

4. Only the WAT was used to derive power performance data while measures of skill were limited to non-game drills done in a gymnasium setting.

5. Only a 6% lemon-lime CHO beverage was used. The CHO was made of sucrose (S) and G powder and contained 110 mg sodium, 25 mg potassium, minerals and vitamins such as chloride and phosphorous, and an osmolality of 280-360 mmols/L.

Limitations of Study

The following limitations existed for this study:

1. The results of this study may only apply to female Division III varsity lacrosse players between the ages of 18 and 22 years.

2. The results of this study may only apply to lacrosse players working in the laboratory or on the field under the exercise protocols described.

3. The results of this study may only apply to power parameters derived from the WAT.

4. The results of this study may only apply to 6% lemon-lime CHO beverage.

5. The results of this study may only apply to protocols described for the skill tests.

Chapter 2

LITERATURE REVIEW

It is well accepted that ingesting cool fluids before, during, and after prolonged exercise is vital to maintaining proper thermoregulation and circulatory function. This practice should reduce the risk of dehydration and hyperthermia, two primary concerns in medical and athletic circles (Houmard et al., 1991; Mitchell & Voss, 1991; Noakes, Rehrer & Maughan, 1991). Previous research has shown that as little as 2% dehydration can adversely affect one's ability to perform physical work (Coleman, 1988; Mitchell et al., 1988; Ryan, Bleiler, Carter & Gisolfi, 1989). The ability to optimize athletic performance is long associated with the consumption of CHO beverages. It is thought that with frequent intermittent doses of a CHO beverage (every 15-20 min), greater amounts of fluid and fuel will be made available which should help spare muscle and liver glycogen. Subsequently, it is thought that CHO consumption will contribute to delayed onset of fatigue and improved performance (Millard-Stafford, Sparling, Rosskopf, Hinson & Dicarlo, 1990; Mitchell & Voss, 1991; Noakes et al., 1991).

Commercial claims and frequent updates in scientific information make it difficult for athletes, coaches and trainers to select the most appropriate CHO beverage. What follows is an attempt to summarize the current research regarding CHO beverages and to delineate their role in exercise and sport activities. The following review emphasizes (a) CHO beverage characteristics and composition, (b) physiological effects of CHO ingested during exercise and, (c) CHO ingestion and exercise performance.

CHO Beverage Characteristics and Composition

For a fluid replacement CHO beverage to be considered ideal several properties must be inherent, including palatability. If the taste is disagreeable, intake will be insufficient (Coleman, 1988; Johnson, Nelson & Consolazio, 1988; Murray, Seifert, Eddy, Paul & Halaby, 1989; Thompson, Wolfe & Eikelboom, 1988). The beverage also must empty rapidly from the stomach into the small intestine and then into the bloodstream (Coleman, 1988; Mitchell et al., 1988; Murray et al., 1989; Naveri, Tikkanen, Kairento & Harkonen, 1989). The drink should be consumed in sufficient volume to promote energy delivery to the working muscles but not increase the risk of gastrointestinal (GI) distress (Coleman, 1988; Murray et al., 1989). It is believed that a beverage containing 6-10% CHO and a small amount of sodium may help to maintain circulatory and thermoregulatory function as well as fluid and electrolyte balance, especially during prolonged exercise in the heat (Coleman, 1988; Mitchell & Voss, 1991; Murray et al., 1989).

CHO Type

Considerable research has been done in the area of CHO type and content relative to exercise performance, yet, a consensus regarding the exact composition and concentration of the ideal beverage does not exist. There are advocates for substrates containing either G, S, fructose (F), or possibly a blend of ingredients such as a maltodextrin (glucose polymer, GP). Nonetheless, findings from a number of investigations are described below which help to explain which exogenous CHO solution is best for producing improved exercise performance.

Palatability of an ingested CHO beverage is the main concern to athletes. It has been shown that one of the major benefits of ingesting commercial sports drinks is that voluntary consumption of fluids is encouraged, thereby, aiding in the prevention of dehydration (Johnson et al., 1988; Murray, 1987). Compared to water (W), S is at the forefront when it comes to taste for most individuals. Although GP was identified in one study as being preferred when compared to W (Millard-Stafford, Cureton & Ray, 1986), S is reported in several studies to be the beverage of choice (Murray et al., 1989; Thompson et al., 1988). It is clear that when compared to W, athletes for the most part, prefer a cool, pleasant tasting substance versus a beverage at room temperature or with no taste, as evidenced by their increased voluntary intake (Hubbard et al., 1984). It is not clear, however, if an athlete, given the choice between various CHO types, would preferably choose S over G or GP.

Another factor to consider when choosing an ideal fluid replacement beverage is whether the solution empties from the stomach at a desirable rate, commonly called: gastric emptying (GE). Poor GE could cause GI distress, and possibly hinder, not enhance performance (Mitchell et al., 1988; Murray et al., 1989). GE is considered to be affected by solution type, volume and concentration. Although some researchers continue to advocate a substrate with a low concentration (e.g., < 3% CHO), most agree that a moderate concentration (6-10% CHO) is best for simultaneously preventing dehydration and enhancing performance. The literature also demonstrates that at rest, 15% GP and 15% F empty faster than a 10% G solution (Sole & Noakes, 1989). In addition, during exercise, W, 10% S, and 10% GP have been shown to empty at similar rates (Candas et al., 1986).

It is clear that F ingestion at moderate to high concentrations during prolonged exercise results in GI distress and perhaps hinders performance (Coleman, 1988). It appears as though F is absorbed at a slower rate and tends to result in GI distress and diarrhea (Fruth & Gisolfi, 1983).

Of the solutions mentioned (S, F, G, GP), all stimulate fluid absorption from the stomach but not necessarily at the same rate. Solutions with F have been identified as having a slower absorption rate into the small intestine. This information compliments literature stating that F has been associated with GI disorders such as diarrhea and nausea (Paul, Seifert, Eddy & Murray, 1988). In addition, xylitol has also been shown to cause GI distress during exercise (Joensen et al., 1986). It seems likely that neither F nor xylitol can be metabolized to glucose rapidly enough to be utilized by the working muscles (Coleman, 1988).

CHO Content

Based on the research, it is now believed that most beverages containing between 6-10% CHO are absorbed into the bloodstream as easily as water but provide benefits that water does not (Millard-Stafford et al., 1990; Murray et al., 1989). However, studies have shown that ingesting CHO beverages with high concentrations (e.g., 12%) results in decreased physiologic responses and may limit performance (Davis, Burgess, Slentz, Bartoli & Pate, 1988; Fruth & Gisolfi, 1983; Lamb & Brodowicz, 1986; ; Mitchell & Voss, 1991). These limitations are likely due to abdominal cramps and other GI disorders (Coleman, 1988; Davis et al., 1988; Murray et al., 1989). GE rates also have been reported to be slower as the CHO concentration increases (Davis et al., 1988; Murray, 1987; Naveri et al., 1989). On the other hand, ingesting beverages with a concentration of 5% or less do not appear to have the same beneficial effect on performance as higher concentrations (e.g., 6-10%).

Although CHO presence is crucial to the content of performance enhancing beverages, it is not the only key ingredient. Electrolytes play a major role in CHO solutions. Not only do they help maintain circulatory and thermoregulatory function but also fluid and electrolyte balance (e.g., salt and potassium), especially during prolonged exercise in the heat (Millard-Stafford et al., 1990; Mitchell & Voss, 1991; Noakes et al., 1991). Common ingredients in all CHO beverages are: water, sugar, salt (Na+), and potassium (K+). Water rehydrates the body, sugar provides CHO for energy, Na+ helps retain water, and K+ helps muscle function.

Many nutritionists and exercise scientists are concerned about the amount of Na+ in commercial sports drinks, feeling that the average balanced daily diet provides more than enough of this ingredient. Although sweat contains water, Na+, and K+, blood plasma contains proportionately less water and, more Na+ and K+, than sweat. Therefore, the concentration of electrolytes in blood plasma increases (due to decreased water levels) as a result of exercise and heat exposure (Coleman, 1988). Individuals who are on Na+ restricted diets should take heed when consuming commercially available sports drinks. Also, Na+ supplements may be undesirable in prolonged exercise or physical activity in high temperatures because imbalances in fluid and electrolytes may occur (Coleman, 1988).

The exercise environment (e.g., heat and humidity) and dietary restrictions are not the only factors of importance when considering electrolyte imbalances. For example, ultra-endurance athletes are especially vulnerable to hyponatremia (i.e., excess Na+ deficit from sweat loss). Although this condition occurs infrequently, it should not be taken lightly. Believed to be complicated by the ingestion of W or no/low Na+ drinks during exercise, the risks of hyponatremia can be reduced substantially with consumption of commercially available CHO beverages containing Na+.

Because Na+ helps to retain W, plasma volume is thought to be maintained and even restored as a result of Na+ ingestion. The amount of Na+ in an 8 ounce serving of a CHO beverage may range from 35-116 milligrams, which is not dangerous for a physically active individual (Coleman, 1988). Literature shows that the highest Na+ containing beverage on the market is Quickick, produced by Cramer Products (116 mg/8 oz serving). Gatorade contains the second highest with 110 mg/8 oz serving (Stokely-Van Camp, 1990). These Na+ levels are comparable to the levels found in one cup of 2% milk which is not a dangerous amount (Coleman, 1988). Specifically, Gatorade is approximately equal to 10-20 milliequivalents of Na+ per liter (Meq/L), considerably lower than that already in plasma (140 Meq/L) (Coleman, 1988). Therefore, nutritionists and exercise scientists need not be alarmed about the amount of Na+ in commercial sports drinks.

Physiological Effects of CHO Ingested During Exercise

Probably one of the most influential factors determining the ideal CHO beverage is whether the beverage empties from the stomach at a desirable rate so as to prevent GI distress (Coleman, 1988; Mitchell et al., 1988; Murray et al, 1989; Naveri et al., 1989). In this section, information on GE will be presented.

In addition, the following includes material on the metabolic aspects of CHO ingestion as they relate to exercise performance.

GI Aspects

GE is one of the primary limiting factors that determines the rate of exogenous CHO delivery to the working muscles. Current methods used to measure GE rates have been highly criticized. Under the strictest laboratory conditions, results are often questionable (Coleman, 1988; Noakes et al., 1991).

Probably one of the most cited investigations concerning the effects of oral substrates and exercise performance is by Costill & Saltin (1974). They determined that ingesting CHO solutions with concentrations greater than 2.5% impaired GE. After subjects ingested either 2.5%, 5%, 10% G or W, they found that at rest, the fastest GE rate occurred with W and then with the 2.5% G solution. Therefore, the practical advice at the time was to ingest solutions with concentrations less than 2.5% CHO. Since 1974, substantial controversy over the concentration of CHO and its effects on GE emerged.

Recent studies have shown that 5-7% CHO solutions empty at rates similar to W (Houmard et al., 1991; Seiple, Vivian, Fox & Bartels, 1983). The controversy is best explained by Ryan et al., (1989) who discovered that studies conducted during 15-30 min of rest or exercise suggested that GE may be slower with solutions greater than 2.5% G (Costill & Saltin, 1974; Neufer et al., 1986). However, when subjects endured 2-4 h of exercise, GE rates of 4.4-10% CHO when compared to W were similar (Candas et al., 1986; Costill, Kammer & Fisher, 1970; Mitchell et al., 1988; Owen, Kregel, Wall & Gisolfi, 1986).

Because, GE is directly affected by the ingested CHO composition, the quantity and content have a great impact. Too much fluid at high concentrations may cause side effects such as abdominal cramps, nausea, and diarrhea (Murray, 1987). The higher the concentration of the beverage, the longer it takes to empty from the stomach, hence, delaying the muscle's ability to utilize the fluid for fuel. Solutions made up of S, G, and GP appear to be better than F in enhancing performance as well as preventing GI disturbances (Houmard et al., 1991; Murray, 1987; Sole & Noakes, 1989).

Due to questionable laboratory techniques, dynamics of the beverage, uncontrollable characteristics of the athlete, and methodologies of the studies, considerable debate continues to exist over the correct volume and concentration of fluid replacement beverages. Although past and current research has identified beverages with concentrations greater than 2.5% CHO to be detrimental to an athlete's performance (Costill & Saltin, 1974; Neufer et al., 1986), most recent literature is in favor of a higher concentration (i.e., 6-10%) (Houmard et al., 1991; Murray, 1987; Sole & Noakes, 1989).

Modality of exercise was thought to have an effect on GE rates, however, currently no literature is available with undeniable results to that effect. GE results for the cycle and the treadmill ergometers do appear to be similar, however, a trend does exist toward decreased GE rates on the treadmill (Houmard et al., 1991). This trend is speculated to be attributed to fluid movement in the stomach caused by the nature of the activity (Brouns, Saris & Rehrer et al., 1987).

Therefore, based on the literature it appears GE rates observed on resting subjects can be generalized to moderate cycle ergometer exercise when W or low caloric content beverages are consumed. In addition, during prolonged exercise, the greatest CHO concentration, volume and content that can simultaneously deliver fluid and enhance performance is yet to be determined.

Although the rate of GE is one of the key characteristics of the ideal fluid replacement beverage, other physiological factors must also be taken into consideration. The effects of CHO ingestion on thermoregulation, and plasma volume control should be investigated.

Thermoregulation

Of concern to most athletes, coaches, medical personnel, and sponsors, is the risk of thermal injury during sporting events and practices. In long races, for example, sweat loss can contribute to a 6-10% decrease in body weight (Wyndham & Strydom, 1969). As little as 2% dehydration has been shown to have a negative effect on one's ability to perform physical work (Coleman, 1988; Mitchell et al., 1988; Ryan et al., 1989). It is believed that ingesting cool fluids before, during, and after athletic events is vital to maintaining thermoregulation and circulatory function (Houmard et al., 1991; Mitchell & Voss, 1991; Noakes et al., 1991; Millard-Stafford et al., 1990). Better thermoregulation and circulatory function leads to delayed fatigue which in turn can produce better performance. In addition, ingestion of S, G, and GP have all been shown to elicit similar responses with regard to thermoregulation. Although W rehydrates the body, it does not replace electrolytes lost via the sweat during exercise.

The body's inability to dissipate heat becomes apparent when it's rate of heat production becomes excessive (hyperthermia), such as during prolonged exercise in the heat and/or humidity. Other thermal injuries which may occur are heat stroke, heat exhaustion, and muscle cramps (Wyndham & Strydom, 1969).

Euhydration has been shown to minimize the gradual increase in the body's core temperature (Costill et al., 1970; Gisolfi & Copping, 1974). The ingested substrate however, must be flavored and cooled to promote adequate voluntary intake. It has been found that fluid replacement can increase by 120% in subjects who consume flavored, cooled beverages (Hubbard et al., 1984).

Similar responses in thermoregulatory and cardiovascular functions have been cited with the ingestion of G, S, and GP. For example, Millard-Stafford (1990) found that a 7% CHO beverage was as effective as a water placebo during 2 h of multi-modal exercise in the heat. An 8.5% CHO supplement was also shown to regulate body temperature and maintain homeostasis as well as W (Yaspelkis & Ivy, 1991). In another investigation, subjects consumed either a 10% GP, 10% G, or a water placebo during 2 h of treadmill work at 65% VO2max. Thermoregulation was found to be similar between runs in the heat with each of the beverages consumed (Owen et al., 1986).

Plasma Volume Control

Ingesting beverages with a concentration of at least 2% but not exceeding 10% CHO have been shown to be similar to W ingestion with regard to some physiological responses. For example, the maintenance of plasma volume, plasma osmolality, total plasma protein content, sweat rate, rectal and skin temperature, plasma potassium concentration, and exercise heart rate (HR) have all been reported to be similar for W and CHO drinks (Murray, 1987).

During exercise, plasma volume can be influenced by numerous factors such as intensity of exercise, level of hydration, environmental conditions, and type of exercise. Treadmill exercise appears to produce lower plasma volume than cycling (Murray, 1987). In general, the more severe the conditions and/or protocol, the lower the plasma volume. More literature exists supporting little or no enhancement in plasma volume with CHO drinks during exercise than reports in support of change (i.e., enhancement of plasma volume)(Mikines, Farrell, Sonne, Tronier & Glabo, 1988; Millard-Stafford et al., 1990; Owen et al., 1986; Yaspelkis & Ivy, 1991).

The change in plasma volume during maximal cycling exercise is said to be 16-20% (Harrison, 1985). The plasma volume loss seen during prolonged, constant workload, exercise in the heat can be directly associated with the pronounced loss of sweat. Fluid replacement before, during, and after extended exercise helps attenuate what would be a dehydration-induced decrease in plasma volume. In addition, plasma osmolality would be maintained, resulting in more efficient cardiovascular and thermoregulatory homeostasis (Murray, 1987).

CHO and Exercise Performance

Many studies have reported various results regarding the exercise performance effects of ingesting a CHO beverage. These assorted results can be attributed to many factors including differences in CHO type, content, protocol, or laboratory procedures. However, the point remains that CHO beverages do appear to enhance endurance type exercise performance.

Although some literature illustrates data collected from subjects exercising on treadmills, most research involving CHO describes their effects during cycling exercise. A few scattered investigations also have involved simulated triathlons, swimming, soccer, or orienteering performance. Therefore, the following review will predominately cover cycling performance results with respect to CHO ingestion. Other modes of exercise will be mentioned where appropriate. Because intermittent versus continuous exercise appears to have no significant effect on CHO and exercise performance or muscle glycogen use (Mitchell et al., 1989), the review of literature will not separate the findings in this manner.

The common premise to studying the effects of CHO on exercise performance is to experimentally evaluate subjects by recording either time to exhaustion at a predetermined work rate (e.g., 75% VO2 max), ability to complete a desired task (e.g., 70 mi cycling ride), or the amount of work accomplished during a specified period of time (e.g., 120 min cycling). Subjects are administered a CHO beverage or sweetened placebo before and/or during and sometimes after an exercise bout. Typically, the drinks are administered in a double blind fashion to reduce experimental bias with subjects acting as their own controls (Murray, 1987). The duration of exercise is usually between 1.5 and 4 h, although some investigations have deviated from either extreme. The total CHO consumed ranges from 50 to over 400 g. Again, the outer edges of this continuum have been surpassed in only a few experiments.

Murray and colleagues (1989) analyzed the effects of CHO content on exercise performance. After subjects ingested either a 6%, 8%, 10% S, or water placebo, results illustrated enhanced performance on 1.25 h of cycling exercise for the subjects who consumed the 6% CHO. It is interesting that the enhanced results were exhibited after only 60 min of cycling exercise. However, similar physiologic function and sensory responses were found despite the content of the CHO ingested. It has previously been thought that only events lasting 90-120 min or more challenge stores of muscle and liver glycogen and therefore show the benefits of CHO beverages (Murray et al., 1989).

Fatigue also has been reported to be delayed by as much as 30 min as a result of a single CHO feeding (Coggan & Coyle, 1989). These researchers found that a single GP feeding (3 g/kg in a 50% solution), late in exercise (after 135 min cycling at 70% VO2max), effectively restored and maintained plasma glucose availability while enhancing exercise time by 21%. Restoring euglycemia and increasing CHO oxidation was believed to delay fatigue. Time to exhaustion in running also has been reported as being positively affected as a result of ingesting a GP (Coggan & Coyle, 1989; Millard-Stafford et al., 1988; Millard-Stafford et al., 1990).

Other types of prolonged endurance events have shown that CHO beverages may be of value during exercise. For example, subjects undergoing simulated triathlons while ingesting CHO solutions have exhibited improved performance. Millard-Stafford and colleagues (1988) found that consuming 230 g of a GP significantly improved run time to exhaustion at 90% VO2 max. During the 90 min of exercise, CHO utilization and blood glucose were significantly higher with the GP than with the placebo beverage by an average of 20% and 15%, respectively. In 1990, Millard-Stafford and associates again studied the effects on triathletes who consumed CHO beverages. They believed that although consumption of commercially available drinks improved cycling performance, it may not have produced the same effects on a multi-modal event due to the requirement of different muscle groups for a relatively short duration. This time, instead of a simulated triathlon with athletes ingesting a GP, the researchers investigated the effects of a 7% CHO beverage on actual participants in a United States Triathlon Series (1.5 km swim, 40 km bike, and 10 km run) in warm conditions. They found that ingestion of the CHO drink leads to increased blood glucose, CHO utilization, and greater exercise intensity.

Kujala and assistants (1989) studied the effects of consuming either 900 ml of a 2.5% G substance or 1300 ml of a combined CHO substance (900 ml G + 400 ml GP) on ability to complete a 16,000 m orienteering course. Participants who ingested the G solution took longest to complete the course (113 min vs 107 min). In addition, three subjects became exhausted during the competition. All three had low serum glucose concentrations and were from the group consuming the G drink. The positive effects of the combined CHO appeared to take place during the last third of the competition as the participants who ingested the G plus GP showed comparatively faster performance during this time (Kujala et al., 1989).

Thus far, the review of literature has primarily evaluated the effects of CHO beverages on individual events such as running or cycling. No mention has been made regarding the possible effects of commercial sports drinks on team sports. However, in 1986, Leatt & Jacobs studied the effects of a CHO solution on athletes during a 90 min soccer match. The uniqueness of this particular study is the fact that it is the first investigation on a team sport to take place in a field versus a laboratory setting and show positive effects on performance.

Ten male soccer players were divided into two groups of equal size based on playing position. The experimental group ingested 500 ml of a 7% GP solution 10 min prior to the game and after 45 min of playing. The control group consumed, at the same designated times, a water placebo. A biopsy of the vastus lateralis before and after the game depicted significantly less muscle glycogen utilization in the experimental group (111 mmol/kg of G) when compared to the control group (181 mmol/kg of G). Because numerous previous studies have demonstrated that GP ingestion during exercise spares muscle glycogen and enhances performance, the researchers concluded that in this case, muscle glycogen utilization was perhaps reduced in the experimental group because of greater oxidation of circulating G (Leatt & Jacobs, 1986). Unfortunately, actual soccer performance measures were not conducted in this investigation.

Unlike Leatt & Jacobs (1986), another group of researchers did investigate performance measures on soccer players and found that CHO supplementation between indoor soccer matches are likely to significantly influence performance in subsequent matches in a favorable manner (Foster, Thompson, Dean & Kirkendall, 1986). During a one hour interval between matches, players consumed either a water placebo or 300 ml of a 25% GP solution. Performance was evaluated via a video-tape of the match. Total yards, yards at a walk-jog pace, and yards at a cruise-sprint pace were tabulated for each player. Both total yards and walk-jog yards were significantly greater after CHO ingestion (4737 vs 4013 yards and 3436 vs 2924 yards) when compared to the water placebo. Although cruise-sprint yards were not significantly different in the second match (CHO vs placebo: 1301 vs 1090 yards), there was a significant difference after CHO (1046 to 1301 yards) versus no significant change after the water placebo (1046 to 1090 yards). Therefore, these researchers suggested that when individuals exercise for a period of time, stop for roughly an hour, then exercise strenuously again, their performance may be favorably enhanced during the second exercise bout if a CHO supplement is ingested between bouts.

Until recently, little mention has been made of the mechanism responsible for generating better performance as a result of consuming commercially available CHO sports drinks. The sparing of muscle and liver glycogen has been reported consistently as a possibility as well as elevated blood glucose used in place of energy stores. The following information will be devoted to discussion of the potential mechanisms responsible for heightened exercise performance.

<u>Mechanisms for Improved Exercise Performance</u>

The mechanism for increased performance with CHO ingestion is still somewhat dubious (Davis et al., 1988; Millard-Stafford et al., 1988; Mitchell, Costill, Houmard, Fink, Pascoe & Pearson, 1987). It is believed that some CHO drinks, specifically G, are useful because of their ability to assist in the absorption of water and electrolytes from the intestine (Navèri et al., 1989). Still, others believe that by replacing the fluid lost via sweat, one enhances the sparing affect on muscle and liver glycogen and/or maintains the blood glucose within the system (Davis et al., 1988; Houmard et al., 1991; Mitchell & Voss, 1991; Naveri et al., 1989).

Maintenance of Blood Glucose

In a study performed by Mitchell and colleagues (1989), subjects who ingested a 12% CHO solution demonstrated elevated blood glucose levels in addition to a lack of glycogen sparing. It was suggested that the maintenance of the blood glucose may be responsible for the increase in performance.

Davis et al. (1988) investigated the effects of 6% and 12% glucose beverages as compared to a water placebo. The results showed that even though performance levels were somewhat higher with the 6% G versus the water placebo, the difference was not significant. The lack of significance was attributed to the low number of subjects and the protocol of the test. Subjects completed all phases of the test under all drink conditions. Traditionally, performance is measured over extended periods of time, during steady state exercise. In this study, three minute, high intensity bouts were used because it simulated race conditions.

Nevertheless, the authors felt that evidence still existed in support of improved exercise performance with the CHO condition. The mechanism characterizing the phenomenon was attributed to possible elevated blood glucose levels and increased oxidation of exogenous glucose. The authors also gave credence to the possibility of muscle glycogen sparing.

Glycogen Resynthesis

The primary source of CHO used during exercise is located in muscle glycogen (Ivy, 1991). This theory was developed with the use of a new muscle biopsy technique during the 1960's. It became apparent that the ability to maintain an exercise work rate between 65 and 75% VO_2max for an extended period of time would depend on one's pre-exercise level of muscle glycogen. The greater the pre-exercise stores of muscle glycogen, the greater the exercise time to exhaustion (Ivy, 1991). Immediately following this finding, researchers tried to determine the most effective method of elevating muscle glycogen stores prior to training or competition as well as how to replenish them after the cessation of exercise (Ivy, 1991). Several theories have evolved as a result of this research.

First, the possible rate-limiting steps to glycogen synthesis were investigated. After much inquiry, it is common belief that the transfer of G across the muscle cell membrane appears to be what limits the rate of muscle glycogen synthesis (Friedman, Neufer & Dohm, 1991; Ivy, 1991). Therefore, it is believed that resynthesis of muscle glycogen is also dependent upon the regulation of G transport across the membrane.

Further, research demonstrated that muscle glycogen levels following the cessation of exercise are not only rapidly restored (Ivy, 1991), but are often brought to levels higher than prior to exercise (Friedman et al., 1991). In addition, complete restoration is said to occur by 24 h postexercise, provided 500-700 g of CHO is ingested (Friedman et al., 1991; Ivy, 1991). In fact, muscle glycogen resynthesis is said to be highest during the first 2 h after exercise (Friedman et al., 1991). Although there appears to be a general consensus as to the rate limiting step to muscle glycogen synthesis and the time frame of complete resynthesis, scientists do not necessarily agree on the type or amount of CHO that is best to ingest for complete muscle glycogen restoration following prolonged exercise.

Although, Friedman et al., (1991), and Ivy (1991) do concur that G is quite effective as a fluid replacement beverage for muscle glycogen restoration following exercise, Friedman et al. suggested that S is just as effective. The two investigators also agree that the ingestion of a beverage with F is recommended since it is most efficient in the replenishment of liver glycogen. In addition, ingesting at least 0.70 g/kg body weight of a substrate (i.e., G, S with F) every two hours after exercise appears to best maximize glycogen resynthesis rate. Consuming greater than 0.70 g/kg of body weight of a substrate appears to be limited by the constraints imposed by GE (Friedman et al., 1991). This value is not quite in agreement with Ivy (1991) who stated that ingesting a beverage with greater than 1 g/kg body weight every two hours after exercise but not exceeding six hours could be counterproductive to muscle glycogen resynthesis. However, it is clear that consumption of simple versus complex CHO is deemed best for increasing muscle glycogen stores during the first four to six hours after a training bout (Friedman et al., 1991; Ivy, 1991).

One segment of research delved into the effect of exercise mode on muscle glycogen stores. After examining seven male subjects enduring three successive days of either running or cycling at 75% VO_2 max for 60 min, investigators found that glycogen levels were significantly less in subjects participating in the cycling bouts (Pascoe et al., 1990). In addition, type II skeletal muscle fibers contained more glycogen than type I fibers. This theory is logical because type II fibers are low in mitochondria, rich in glycogen, have a low aerobic capacity and therefore, fatigue easily due to their glycolytic reliance (Powers & Howley, 1990).

<u>CHO Dosage During Exercise</u>

Because results have been published exhibiting enhanced performance as a result of several different types and concentrations of CHO, it is not surprising that the actual recommended dosage to improve performance is questionable (Mitchell et al., 1989). After subjects consumed either a 6%, 12%, or 18% CHO beverage intermittently, exercise performance was measured to determine which concentration had the greatest positive effect on work output (Mitchell et al., 1989). The results illustrated that individuals ingesting 74 g/h exhibited the greatest benefit in performance, while the smaller and moderate doses (11 and 37 g/h) appeared to be inadequate. The smaller dose did show some performance improvements while the moderate dosage resulted in greater fluid related complications. In addition, although dehydration may be prevented using large serial feedings, performance may be impaired as a result of the large gastric residues which cause discomfort (Mitchell & Voss, 1991). It is interesting to note that in the same investigation, continuous, compared to intermittent exercise, did not provide any added benefit relative to performance nor did it alter muscle glycogen use. Intermittent cycling exercise was also used as a protocol in a previously mentioned study performed by Murray and associates (1989). Murray noted an increase in performance after only 60 min of CHO ingestion.

Summary

Deciphering the ultimate formulation of a CHO beverage for the purpose of exercise performance enhancement is quite a challenging task. Yet to be established is the ideal beverage concentration, volume, frequency of consumption, and mechanism responsible for improved performance. Associated relevant factors that should be simultaneously considered include the GE rate, absorption rate, and palatability. Studies have been performed with various protocols, procedures, and variables. Examples of consumed beverages in these studies include: S, G, F, GP, xylitol, cornstarch, various juices, and water placebo. These various beverages have been reported to enhance performance in some manner or at least not inhibit it with the exception of F which has been found to inhibit performance on some occasions. In addition, concentrations utilized range from 2.5-18%. All have been shown to affect performance in a neutral or positive manner. A concentration as high as 50% was reported to increase time to fatigue by 21%.

It is obvious, however, that fluid replacement beverages can be consumed for the purpose of enhancing performance or delaying fatigue. It is likely, that a prudent recommendation for utilizing a CHO beverage is to consume a moderate concentration of 6-10%. The beverage should be made of S, G or GP. The ideal beverage appears to be specific for the individual, with caution being associated with the potential for GI distress. Generally, F has been frequently attributed to abdominal cramps, diarrhea, and nausea. Plain water can be consumed so as to prevent heat related illnesses, however, no added advantage is gained in terms of performance. Fluids should be consumed every 15-20 min during exercise but if possible should mimic consumption during practices and competition (Coleman, 1988). During exercise in hot weather, the beverage should contain a small amount of sodium to help maintain blood volume (Coleman, 1988; Davis et al., 1988; Millard-Stafford et al., 1990). The beverage should provide a source of CHO for use by the working muscles during intense training but not compromise GE or fluid absorption (Coleman, 1988; Murray et al., 1989). Perhaps most of all, the beverage should be palatable (Coleman, 1988; Murray et al., 1989).

Chapter 3

METHODS AND PROCEDURES

The methods of this study are explained in this chapter. It includes the following sections: (a) selection of subjects, (b) methods of data collection, (c) treatment of data, and (d) summary.

Selection of Subjects

This study was conducted during the months of February to May. Nine female subjects participated in controlled laboratory testing while four of the same nine, plus an additional four subjects, participated in a field experiment. The subjects were recruited by the investigator through personal contact and were members of the Ithaca College Varsity women's lacrosse team with ages ranging from 18-22 years old. Some team players elected not to participate therefore, not all team members were used in the study. Volunteers read and signed an informed consent form (Appendix A) describing the procedures and risks associated with this study. In both laboratory and field settings, subjects were expected to drink either a CHO beverage or a placebo before, during and after exercise.

Methods of Data Collection

Baseline Data Collection

The following data were collected during baseline testing: body weight (BW), maximal heart rate (MHR), and maximal workload. Workload and MHR were determined by a graded exercise test (GXT) on a Bodyguard cycle ergometer and on a Cybex Upper Body Ergometer (UBE). Protocol for GXT on the cycle and the UBE can be found in Appendices B and C respectively.

During the visit for baseline data, the subjects also performed 100 practice trials with a Dekan RT Device (model #741), three separate trials of the WAT, and three standing long jumps (SLJ) for practice. The RT trials were split into two sets of 50 trials where simultaneous measurement of SMVT was also recorded. The order of events for baseline data collection was as follows: (a) weight, (b) GXT cycle, (c) 50 trials RT/SMVT, (d) WAT trial one, (e) GXT UBE, (f) WAT trial two, (g) 50 trials RT/SMVT, (h) WAT trial three, and (i) three SLJ trials. The WAT and RT protocols can be found in Appendices D and E, respectively. The speeds and order used for RT can be found in Appendix F. Subjects were not instructed in the lacrosse shooting drills during baseline testing because this was done during team practice sessions prior to data collection. Protocol for shooting drill A and B can be found in Appendices G and H.

Laboratory Data Collection

The purpose of the laboratory setting was to control extraneous variables that could not be managed during field testing. In the laboratory, the test administrator was better able to control the environment, protocol, and workload while at the same time measure variables such as blood G and HLA, RT, SMVT and power (i.e., AP and PP). Subjects alternated submaximal exercise on both the cycle and UBE for 120 min during which time the test administrator monitored not only workload but HR, blood G and blood HLA. Following exercise, subjects executed three SLJ and a modified WAT as measures of power. Skill tests were then performed. Each subject was asked to complete two lacrosse shooting drills; one was a measure of accuracy and speed, while the other measured accuracy. Subsequently, each subject performed a reaction time test in which she was asked to respond to a visual stimulus.

Exercise workload for subjects was set at 80% MHR (approximately 70% VO_2 max) achieved during the cycle and UBE baseline tests. Heart rate (HR) was monitored continuously and recorded every 10 min during baseline and laboratory testing using a Uniq CIC HR monitor. Two subjects (one treatment, one control) participated for a 3.5 h time period with the second subject stagger-started on the exercise protocol 30 min after the first. The following procedure was used for each subject: (a) 10 min after arriving, resting heart rate (RHR) was recorded and the subject was given 6 ml/kg of either a 6% CHO or, placebo which was commercially prepared to give the same appearance, taste, and smell as the CHO solution, b) subject pedalled cycle at 80% MHR for 10 min, c) subject cranked UBE at 80% MHR for 10 min and, d) subject ingested 3 ml/kg CHO beverage or placebo. This procedure (steps b-d) was repeated until the subject had worked for a total of 140 min. Each subject drank every 20 min for a total of eight times including a drink at rest and one after the final exercise bout. Blood was drawn from the finger tip of the non-dominant hand/finger at rest and three times during exercise (60 min, 100 min, 140 min). Blood lactate and glucose levels were determined subsequently using a YSI Model 23A Glucose Analyzer and the YSI Model 23L Lactate Analyzer.

The WAT, a power test in which the subject pedalled as fast as possible for 30 s was then performed. The protocol was as follows: (a) subject began pedalling at which time the workload was gradually increased from zero to the subject's predetermined submaximal exercise point, (b) subject was then given the command "go" and was instructed to pedal as fast as possible for a 30 s duration, (c) at the end of the 30 s time period, the subject was given the command "relax" and was asked to continue to pedal slowly for approximately 15 s, (d) subject was then instructed to get off the cycle. Velocity, force and power were recorded every 5 s via a computerized program connected to the cycle. Power was further broken down to determine average and peak power output. Three SLJ trials were performed as a power measurement and recorded. Next, the subject participated in two lacrosse shooting drills in which 10 shots were taken during each drill.

The first shooting drill was timed for speed and scored for accuracy. The procedure was as follows: (a) four cones were placed in front and to the right side of the goal and four cones were similarly placed on the left side, (b) all cones were in a zig-zag formation aligned with the outside goal pipe and placed 12 m away from the goal, (c) five shots were taken from the right side and five shots were taken from the left side of the goal, (d) the subject then performed a "ground ball pick-up" (i.e., picked up the ball off the ground with the head of the lacrosse stick) at the cone farthest from the goal, (e) the subject then ran as fast as possible through the cones and released a shot by the 8 m line, (f) the subject proceeded to the opposite side to perform a ground ball pick-up, zig-zagged through the cones and again released a shot at the 8 m mark, (g) this procedure was repeated for eight more trials. All trials were timed together to give one speed measurement. In addition, points were awarded for scoring in the proper area allowing for a shooting accuracy measurement.

The second drill's procedure was as follows: (a) subject performed a "ground ball pick-up" 10 m from the goal with the lacrosse stick, (b) subject ran back two additional meters from the goal to 12 m, then ran forward to the goal to the 8 m mark and shot at a designated area. This procedure was repeated nine more times with the ball rotating from three different positions along the 10 m mark for the pick-up. A shooting net was placed on the pipes of the goal to prevent shots from scoring in less favorable areas such as the middle of the goal. Only the four corners of the goal were exposed for possible goal scoring. The four corners were considered designated areas. Shots landing in the corner requested were awarded three points. Shots hitting either pipe adjacent to the correct goal scoring area earned two points and, shots hitting any other part of the goal resulted in one point. Total possible points for this shooting accuracy drill was 30. The subject kept moving at all times during these drills to minimize metabolic recovery.

Following the two shooting drills, each subject performed 20 RT trials in which the subject moved her hand from one sensor (RT) to another sensor (SMVT) at the first sight of a visual stimulus. The length of time between the ready signal and the stimulus was randomly varied to keep the subject from anticipating and prematurely hitting the sensor prior to the appearance of the stimulus. Each subject was allowed to practice roughly 10 trials or until she felt ready before the actual administration of the RT test. Five control trials were instituted within the 20 trials to prevent the subject from prematurely moving prior to the visual stimulus.

The 140 min endurance effort and laboratory tests were performed twice on separate days. Subjects ingested the CHO beverage during one test session and the placebo during the other test session in a counter-balanced fashion to minimize an order effect.

Field Data Collection

The purpose of the field data collection was to allow the athletes to perform in a typical lacrosse practice environment. The subjects consumed a CHO or placebo beverage throughout the practice session and executed the same shooting drills used in the laboratory testing at the end of the session. Of the eight subjects who participated in the field test, four were involved in the laboratory test as well. Again, each subject acted as her own control by participating in the field study twice on separate days, once with the ingestion of the CHO drink and once with the flavored placebo.

The subjects participated in a strenuous 2.5 h lacrosse practice on a grass field. The practice was intentionally physically demanding to fatigue the athletes. Participants ingested 6 ml/kg of either the CHO drink or the placebo prior to practice commencement. Every 20 min, subjects ingested 3 ml/kg of one of the beverages. Half of the subjects ingested the CHO and half ingested the placebo in the first practice field test. The conditions were reversed on the second day of field testing. The drinks were again administered in a double-blind fashion meaning that neither the athlete nor the investigator had any knowledge of which cooler contained the CHO beverage. At the end of the practice session, players performed the same two shooting drills as described above. These data were gathered in the same fashion as described for the shooting tests in the laboratory testing session.

Treatment of Data

For the laboratory data, dependent t-tests were used to analyze skill performance whereas a multivariate analysis of variance (MANOVA) was used to analyze WAT anaerobic power. In addition, a 2 x 4 (Condition x Time) repeated measures analysis of variance (RM-ANOVA) technique was used to determine the effects of CHO beverage consumption during prolonged exercise on HLA and G levels in the blood. A doubly MANOVA was used to compare CHO versus placebo in a one-way design for RT and SMVT. For the field test data, a t-test was used to analyze skill performance.

Summary

In this chapter, the methods of this study were detailed by discussing subject selection, methods of data collection, and treatment of data. It was through these methods that the hypotheses were tested. Specifically, these methods allowed for the determination of the effects of CHO versus placebo on skill performance, anaerobic power, RT, blood G and blood HLA. The laboratory as well as a field setting was used to test the hypotheses. Specifically CHO ingestion was studied to determine if an individual could score more goals, produce more anaerobic power and/or react faster. In addition, blood HLA and G were analyzed to determine if CHO ingestion altered physiologic response during intense athletic performance.

Chapter 4

RESULTS

The general purpose of this study was to investigate the effects of CHO ingestion on indicators of athletic performance. The primary objective of the study was to determine the effect of the CHO test solution on lacrosse skill performance, specifically shooting on goal, both in the laboratory and on the field. The secondary objective was to determine the effects of consuming a CHO beverage on AP, PP, blood HLA, blood G, RT and SMVT, all of which were investigated in a controlled laboratory environment.

Analysis of Skill Performance

Descriptive statistics and dependent t-test results for laboratory tested lacrosse skill performance can be found in Table 1. Each subject received two shooting drill scores and one speed score for CHO and placebo conditions. The mean score for shooting drills A and B were slightly greater for the placebo condition than for the CHO condition, neither difference achieved significance. A difference between CHO and placebo for the speed variable existed, however this trend toward significance ($p = .07$), with CHO

Table 1

Descriptive Statistics for Lacrosse Skill Performance After Completing 120 Minutes of Submaximal Exercise in an Exercise Physiology Laboratory

Source	N	M	SD	p
Shooting Drill A				0.29
CHO	9	7.7	3.4	
PLACEBO	9	8.7	3.6	
Shooting Drill B				0.39
CHO	9	11.4	5.2	
PLACEBO	9	12.1	4.4	
Speed				0.07
CHO	8	114.1	12.3	
PLACEBO	8	119.6	14.2	

CHO = Carbohydrate
Shooting Drill A = Number of points scored while being timed
Shooting Drill B = Number of points scored for shooting in designated area.
Speed = Number of seconds needed to shoot 10 lacrosse balls at goal

ingestion positively affecting performance, did not achieve the .05 standard.

Descriptive statistics and dependent t-test analysis for field lacrosse skill performance can be found in Table 2. As with the laboratory data, each subject received two shooting drill scores and one speed score for the CHO and placebo conditions. The same drills used in the laboratory setting were used on the field with the difference between the two settings being close control over the workout characteristics in the laboratory trials. No significant differences surfaced between the CHO and placebo conditions ($p<.05$) except during Shooting Drill B. Mean scores for CHO were significantly greater than for placebo ($p = .03$).

Analysis of Anaerobic Power

A modified WAT was used to determine the subject's anaerobic power, specifically AP and PP. Using a one-way doubly MANOVA, AP and PP were analyzed after 140 min of exercise (see Table 3). Performance was significantly better on the modified WAT when the CHO beverage was ingested than when the placebo was ingested (Wilk's Lambda (2,5) = .179, $p = .013$). Descriptive statistics and t-test results for the WAT

Table 2

Descriptive Statistics for Lacrosse Skill Performance After Completing a Typical Varsity Practice Session

Source	N	M	SD	p
Shooting Drill A				0.40
CHO	8	7.5	7.0	
PLACEBO	8	6.8	2.3	
Shooting Drill B				0.03*
CHO	8	6.9	3.8	
PLACEBO	8	3.6	1.6	
Speed				0.25
CHO	8	110.6	12.4	
PLACEBO	8	107.6	14.2	

CHO = Carbohydrate
Shooting Drill A = Number of points scored while being timed.
Shooting Drill B = Number of points scored for shooting in designated area.
Speed = Number of seconds needed to shoot 10 lacrosse balls at goal.
*p<.05.

Table 3

One-Way Doubly MANOVA Summary Table for Average Power and Peak Power Obtained from the Modified Wingate Anaerobic Test

Source	Wilk's Lambda	*df*	Approx *F*	*p*
Condition	.17854	2,5	11.50	.013

*p < .05

can be found in Table 4. Post-hoc analysis revealed that although CHO scores were better than placebo scores for both AP and PP, only PP was statistically significant ($p = .05$).

Analysis of Blood Lactate Levels

A RM 2 X 4 ANOVA (Condition x Time) was used to determine the effects of CHO beverage consumption during prolonged exercise on HLA levels in the blood. The ANOVA results show that while the interaction was not significant ($F\ (3,24)=1.80$, $p > .05$), the condition main effect was significant ($F\ (1,8)=8.49$, $p < .05$). Descriptive statistics showed mean scores for blood HLA levels were higher with the CHO beverage ($M = 2.07$ mmol) across all four times (i.e., 0, 60, 100, 140 min) than when the placebo was ingested ($M = 1.68$ mmol). The time main effect was also significant ($F\ (3,24)=10.08$) (see Table 5) and dependent t-tests were performed to follow-up this significant main effect (see Table 6). The contrasts that were significant were between 0 min and 60 min and between 60 min and 100 min. No significant difference between times was found at 100 min and 140 min.

Table 4

Descriptive Statistics for Average Power and Peak Power Obtained from the Modified Wingate Anaerobic Test

Source		N	M (watts)	SD	p
AP					0.15
	CHO	9	247.29	93.48	
	PLAC	9	204.71	43.65	
PP					0.05*
	CHO	9	294.29	102.01	
	PLAC	9	226.14	46.59	

AP = the average of watts recorded every 5 seconds during 30 second cycling bout.

PP = peak watts recorded during 30 second cycling bout.

*$p < .05$.

Table 5

Repeated Measures ANOVA Summary Table for Blood Lactate

Source	SS	df	MS	F	p
Within Subjects Design					
Condition (C)	2.70	1	2.70	8.49	.019*
C X S	2.54	8	.32		
Time (T)	18.50	3	6.17	10.08	.000**
T X S	14.68	24	.61		
C X T	1.12	3	.37	1.80	.173
C X T X S	4.96	24	.21		

*p <.05.

**p <.001.

Table 6

Descriptive Statistics for Blood Lactate

Source	N	M (mmol)	SD	p
Lactate				0.0001*
0 min	18	1.17	.73	
60 min	18	2.59	.85	
Lactate				0.006**
60 min	18	2.59	.85	
100 min	18	1.96	.82	
Lactate				0.18
100 min	18	1.96	.82	
140 min	18	1.78	.60	

*$p < .001$.

**$p < .01$.

Analysis of Glucose

A 2 X 4 RM ANOVA (Condition x Time) was used to determine the effects of an ingested CHO beverage on glucose levels in the blood during prolonged exercise. The ANOVA results show that the interaction effect was significant (F (3,21) = 5.27, p <.05) (see Table 7). Dependent t-tests between conditions at each time point were performed to follow up the significant (p <.05) interaction (see Table 8). The contrast that was significant was between CHO and placebo at 60 min with the CHO condition producing significantly higher blood glucose levels. At 140 min, the difference between CHO and placebo conditions was very close to significance (p = .058) with the CHO condition again greater than the placebo. No significant differences were found at 0 or 100 min.

Analysis of RT and SMVT

Descriptive statistics for RT and SMVT can be found in Table 9. RT and SMVT scores were based on subject's ability to respond to a visual stimulus. The mean RT score for CHO was very similar to that for placebo (M = 214.8 vs. 217.3 ms respectively). The same held true for SMVT (365.4 vs. 367.9 ms). A doubly

Table 7

ANOVA Summary Table for Blood Glucose

Source	SS	df	MS	F	p
Within Subjects Design					
Condition (C)	169.98	1	169.98	1.61	.245
C X S	739.71	7	105.67		
Time (T)	659.41	3	219.80	5.08	.008*
T X S	909.04	21	43.29		
C X T	321.89	3	107.30	5.27	.007*
C X T X S	427.39	21	20.35		

N=9

*p <.05.

Table 8

Descriptive Statistics for Blood Glucose

Source	N	M (mg%)	SD	p
Glucose 0 min				0.437
CHO	9	88.7	9.7	
PLAC	9	81.3	6.2	
Glucose 60 min				0.018*
CHO	9	76.9	8.2	
PLAC	9	69.9	1.9	
Glucose 100 min				0.110
CHO	9	73.3	9.9	
PLAC	9	69.6	2.9	
Glucose 140 min				0.058
CHO	9	79.7	12.4	
PLAC	9	72.0	4.6	

*$p < .05$.

Table 9

Descriptive Statistics for Reaction Time and Speed of Movement

Source	M (milliseconds)	SD
RT		
CHO	214.825	41.421
PLACEBO	217.300	34.290
SMVT		
CHO	365.463	68.868
PLACEBO	367.950	57.177

Note: Low score is best

N = 8

RT = Reaction Time

SMVT = Speed of Movement

CHO = Carbohydrate

$p < .05$.

MANOVA was used to compare CHO versus placebo in a one-way design for RT and SMVT. Results showed no significant differences for the MANOVA on these variables.

Summary

This chapter contained statistical analyses of skill, power, hemeanalysis, and reaction time performance with regard to CHO beverage ingestion. CHO ingestion did not enhance the performance of sport specific skills (except shooting drill B in the field setting only) nor reaction time. However, significant results for short-term power performance and hemeanalysis were evident between CHO and placebo conditions. The test solution proved to be beneficial in permitting significantly more power, which is thought to be directly related to the increased availability of circulating blood glucose. Therefore, while commercial CHO beverage consumption did not enhance skill performance, it did positively affect selected indicators of athletic performance.

Chapter 5

DISCUSSION OF RESULTS

The findings of this study demonstrate that the use of a commercial CHO beverage positively affects selected indicators of athletic performance. The CHO solution proved to be beneficial in permitting significantly more power output on a 30 s performance test. CHO ingestion did not however, appear to enhance performance of sport specific skills, namely the goal scoring ability of lacrosse players. A discussion of these results are presented in this chapter under the following subtopics: (a) lacrosse skill performance, (b) power performance, (c) blood parameter analysis, (d) RT/SMVT performance, and (e) summary.

Lacrosse Skill Performance

Lacrosse goal scoring ability, as measured by standardized tests, appears to be unaffected by CHO beverage ingestion. In the present study, only during shooting drill B while field testing did subjects score more goals when they ingested the CHO. Only one other study exists that investigated skill performance with respect to CHO ingestion (Jones, Wood, McEnroe, Black & Sforzo, 1993). The Jones et al. (1993) study with soccer players also showed no general benefit to controlled tests of skill with CHO ingestion. In this study, 16 female soccer players underwent a rigorous and well controlled two-hour practice in which a placebo or CHO was consumed (3 ml/kg) every 20 min, and then performed shooting, dribbling and volleying tests. Results showed no significant differences between CHO and placebo ingestion for any of the skills. While one shooting drill in the present study was found to be significantly enhanced with CHO ingestion, this result should be interpreted with caution. First, all other measures of skill made in both test environments were not found to be significantly affected by CHO ingestion. Second, a large number of statistical comparisons were made in this study with a modest sample size. It would not be prudent to place too much emphasis on this sole positive finding given that it is possible that the statistical difference in this isolated case may have occurred by chance.

Although not statistically significant in the present study, mean scores for speed, both in the lab and on the field, were better in the CHO condition. On the standardized shooting test, subjects moved an average of four seconds faster in the laboratory and 10 seconds faster on the field when the CHO beverage was ingested. A top level athlete might consider such improvements in speed to be of practical significance. Reference to enhanced speed with CHO consumption during competition has been previously made. Foster et al. (1986) found CHO supplementation between indoor soccer matches lead to improved cruise-sprint ability when compared to a water placebo. Players were able to move faster for longer periods of time following ingestion of a CHO. Player's were video-taped for cruise-sprint ability during two indoor soccer matches. During the one hour between matches, athletes drank either a WP or 300 ml of a 25% GP. The total cruise-sprint yards in the second match were significantly greater than during the first match after ingesting the CHO solution.

While it is possible that CHO ingestion simply does not impact lacrosse performance as defined in this study, several technical reasons may also account for the lack of significance found in these skill and speed measures. First, it is believed that the endurance protocol of the test may have contributed to the lack of effect upon the dependent variables. The cycle exercise was standardized across groups by relative exercise intensity indicated by HR, versus standardizing by workload. This protocol ultimately contributed to the placebo group performing less work than the CHO group. Not standardizing by workload may have affected fatigue factors that could have ultimately equalized the between group results on the shooting drills. Changing the protocol so that no adjustment of workload occurred if HR varied may have been the key ingredient necessary on the speed test where the p value ($p = .07$) was close to significant. Most other tests, however, did not approach significance and it is not clear if this design change would matter at all.

Second, our skill testing measures may have caused a limiting effect that made it difficult to detect differences between conditions. It is believed that the degree of difficulty to score on the shooting drills was extremely high even for the most experienced athletes. This factor may have ultimately contributed to low goal scoring in both conditions. In these tests, a cover net was placed over the mouth of the goal only exposing a very small portion of each of the four corners. The size of the area available to obtain points was perhaps too small to allow for adequate success. Most athletes received no points on numerous attempts versus a more desirable scenario with the majority of athletes obtaining partial or full credit on almost all attempts. Accordingly, a basement effect on these tests may have limited any effect of the treatment.

Third, only eight subjects were used on the field and nine in the laboratory. Perhaps with a larger sample size significance may have occurred where differences existed. That is, a greater statistical power may be required in a study of parameters such as these.

While it must be concluded that CHO ingestion does not seem to enhance lacrosse skill performance, the limitations and generalizability of this study must be kept in mind. Further studies are recommended before the final word is said on the issue of CHO ingestion during sport performance.

Power Performance

AP and PP were tested in the laboratory and PP was significantly greater when CHO was ingested. Previous studies demonstrated that performance rides following prolonged endurance exercise typically can be done at greater workloads with CHO ingestion when compared to a water placebo (Coyle, Coggan, Hemmert & Ivy, 1986; Millard-Stafford et al., 1988; Millard-Stafford et al., 1990; Mitchell et al., 1988 and Murray et al., 1987). Therefore, it is not surprising that CHO ingestion facilitated power performance on the WAT in the present study.

Although a muscle biopsy was not performed, it appears as though the skeletal muscle fibers were more adequately supplied with glucose allowing greater glycogen sparing which may have allowed for greater muscle force. Leatt and Jacobs (1986) conducted a study in which a muscle biopsy was performed on 10 male soccer players after competing in a 90 minute game and drinking 500 ml of 7% CHO. Significantly less muscle glycogen stores were found in the placebo group. In the present study, significantly more glucose was found in the blood at 60 min. At 140 min into endurance exercise, glucose levels were nearly significant ($\underline{p}$ = .058) between conditions. The WAT was performed directly following the blood withdrawal at 140 min.

Accordingly, it appears that improved circulating blood glucose may have contributed positively to the significantly improved power measure in the present study.

Blood Parameter Analysis

Blood G levels showed an interaction between condition and time. Blood G was significantly higher during the CHO condition than during the placebo condition at 60 min into endurance exercise. The trend toward significantly greater G at 140 min with the CHO condition was also apparent with $p = .058$. Greater G levels in the blood with CHO ingestion throughout exercise is well documented (Millard-Stafford et al., 1990; Mitchell & Voss, 1991; Mitchell et al., 1988; Murray et al., 1987 and Murray et al., 1989).

From the start of exercise to 60 min, the G level during CHO ingestion remained constant while with placebo it dropped drastically. This is logical because during exercise, muscle cells use G for energy during muscle contraction (Powers & Howley, 1990). With placebo there is a need to tap into pre-existing blood G whereas with CHO ingestion subjects were able to utilize the new CHO. Mitchell and Voss (1991) found that in all three cycling trials involving light to heavy volumes of CHO ingestion, G levels were significantly higher at 60 min for the CHO condition than at rest when compared to a WP. Other researchers supported this finding as well (Davis et al., 1988; Millard-Stafford et al., 1990; Mitchell et al., 1989).

The significance of greater glucose availability to sparing muscle glycogen and subsequent power performance was already mentioned. It is noteworthy that in this study, despite having done more external work, subjects could maintain G levels and produce greater power output at the end of the endurance work when in the CHO condition.

The mean scores for HLA at rest during this investigation was 1.3 mmol/l for CHO and 1.1 mmol/l for placebo. This is logical as blood HLA typically stays at about 1 mmol/l at rest when the rate of removal and production are balanced (Powers & Howley, 1990). The present study showed that there was not an interaction between CHO and placebo blood HLA levels. In other words, blood HLA changed across the four points (0, 60, 100 and 140 min) in a similar fashion for both conditions, although, the level was generally greater when the CHO was consumed. The reason for this greater magnitude is likely attributed to the test protocol. As mentioned previously, the CHO group performed more work, hence finding more HLA in the blood during this condition is not surprising. Therefore, according to research, HLA levels for both groups behaved as expected as the CHO ingestion had no effect on the HLA curve (Millard-Stafford, Cureton & Ray, 1988; Millard-Stafford et al., 1990; Murray et al., 1987; Murray et al., 1989).

Reaction Time and Speed of Movement Performance

RT and SMVT scores appear to have been unaffected by ingestion of the CHO solution. Because this was a novel aspect of the present study, literature is unavailable to make comparisons. Hypothetically, maintaining circulating G may have been beneficial to central nervous system function and this might have been reflected in motor speed and sport skill measures. In this investigation, however, CHO and placebo conditions produced similar results for RT and SMVT thereby not lending support to this line of reasoning.

Summary

Lacrosse skill performance appears to be unaffected by CHO beverage ingestion as determined by analysis of goal scoring ability, RT and SMVT results. However, given the nature of some of these findings and limitations/generalizability of this study, future study in this area is recommended. CHO ingestion did significantly facilitate ability to generate more power during a performance ride and produce more total work during the endurance bout. This is thought to be attributed to the greater availability of circulating blood G which was seen in this study. No significant differences were found with RT and SMVT scores. Therefore, while the commercial CHO beverage consumption appeared to positively affect selected indicators of performance, the test solution did not enhance sport skill as measured in the present study.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents an overview of the entire experiment. The chapter is divided into three sections: (a) summary, (b) conclusions, and (c) recommendations.

Summary

The purpose of this study was to assess whether CHO ingestion, if taken intermittently during prolonged exercise, could significantly enhance indicators of athletic performance. To obtain the results, nine female subjects participated in a controlled laboratory experiment, while four of the same nine plus an additional four subjects participated in a field experiment. All subjects acted as their own control.

Subjects reported to the lab on two separate days for data collection on their physical performance which took approximately 3.5 h. The subject received either a 6% CHO beverage made up of sodium, potassium, chloride and phosphorous; or a cool, flavored placebo identical in taste, smell, appearance, and consistency to the test solution. Two subjects began testing during each session with a 30 min stagger start. One subject received the CHO drink whereas the other the placebo. The investigator, laboratory assistants, and the subjects were unaware of which beverage was the test solution.

Ten minutes after arrival, a RHR was determined on the first subject. Blood was then drawn at rest, 60, 100 and 140 min to determine blood G and HLA levels. Subject was given 6 ml/kg of either a CHO beverage or a placebo prior to exercise and 3ml/kg every 20 min during exercise. Subjects rode on a cycle ergometer at 80% MHR (determined during baseline testing) for 10 min, then cranked the UBE at 80% MHR for 10 min. This sequence of alternating on the ergometers was repeated until subject exercised on each piece of equipment seven times. Subjects' HR's were recorded every 10 min. exercise bout.

The WAT test was then used to measure anaerobic power. Average and peak power were recorded every five seconds via a computerized program connected to the cycle. Subject then ran to a gymnasium and performed two lacrosse shooting drills, one for speed/accuracy and the other for just accuracy. Scores and HR were recorded as the subject returned to the laboratory.

Subjects then performed 20 reaction time trials in response to visual stimuli. Reaction time was the time it took the subject to move her hand off the resting pad when the light was seen. Speed of movement was the time it took the subject to move her hand from the resting pad to the stop pad. Each subject was allowed to practice ten trials or until she was deemed ready. One last HR was recorded upon completion of the test.

On two additional, separate days, subjects participated in a demanding varsity lacrosse practice for 2 h out on the playing field. Subjects, ingested 6 ml/kg of either a CHO beverage or placebo before practice and 3 ml/kg every 20 min during practice. Each subject performed the same two shooting drills as performed in the controlled laboratory setting at the end of the field test practice.

Skill performance was analyzed using dependent t-tests. Power and RT/SMVT were analyzed using a doubly MANOVA. A 2 X 4 RM ANOVA for groups and time was used to analyze HLA and G. Post-hoc dependent t-tests were used to follow up significance with power and hemeanalysis. CHO ingestion did significantly facilitate ability to generate more power during a performance ride and more total work during the endurance test. This is thought to be attributed to the greater availability of circulating blood G which was seen in this study. No significant differences were found with RT/SMVT scores. Therefore, while the commercial CHO beverage appeared to positively affect selected indicators of performance, the test solution did not enhance sport skills as measured in the present study.

Conclusions

1. Skill performance appeared to be unaffected by the test solution. Only in shooting drill B during field testing did subjects score more goals when the CHO was ingested. However, due to other results obtained, this result should be interpreted with caution. Test protocol and small sample size could have affected the opportunity to obtain positive results.

2. Anaerobic power increased substantially with CHO ingestion as seen by PP results obtained during a performance ride. Therefore, intermittent CHO ingestion did appear to enhance anaerobic power in this investigation.

3. Blood HLA level demonstrated a significant time main effect with the contrast between 0 and 60 min, and 60 and 100 min. The rate of change over time between the CHO and the placebo condition was similar.

4. Ingestion of a CHO beverage significantly affected G levels in the blood at 60 min with a strong trend toward significance at 140 min. It was this elevated blood G level that was identified as the contributing factor toward significantly enhanced anaerobic power and workload performance.

5. No significant differences were recorded in RT or SMVT. It appears as though the time it took for a subject to react to visual stimuli as well as the speed to move to the electronic hand pad was not affected by CHO ingestion.

Recommendations

Upon completion of the study, the following recommendations for further investigation are deemed appropriate:

1. Standardize cycle exercise across groups by workload as opposed to standardizing by relative exercise intensity indicated by HR. In this study, exercise intensity was decreased or increased based on

the subject's HR so as to avoid maximal exhaustion and ensure completion of the test. This method lead to adjusting the workload on the appropriate ergometer so as to maintain 80% maximum HR. Therefore, the subject actually performed more work when the CHO was ingested, as illustrated by the results.

2. A shooting net with a larger area to score, plus a point system with more variability should be utilized.

3. Catheterization should be utilized to obtain blood samples versus the finger prick method so as to ensure adequate quantity and reduce the likelihood of technical difficulties with collection.

4. Subjects in this study performed one specific sport skill (i.e., lacrosse goal scoring ability). Further research is needed in not only lacrosse but other sports as well. For example, shooting, in addition to passing, dribbling, throwing, catching, tackling and hitting could be used as variables.

Appendix A

INFORMED CONSENT FORM

1. a) Purpose of the study:

The purpose of the study is to investigate the effects of ingestion of a commercial beverage on skill performance.

b) Benefits:

Information from this study will help us determine how effective ingestion of a commercial beverage, similar to "Gatorade", will have on skill performance. Data gathered could be quite beneficial to educators, coaches and athletes. In addition, feedback on performance will be given to players and group data will be given to the head coach.

2. Method:

You will be assigned to one of two groups and then asked to participate in two field sessions lasting approximately 30 minutes on two separate days following a traditional lacrosse practice. In addition, you will be asked to ingest a beverage prior to practice. Furthermore, you will be asked to participate in two sessions in the exercise physiology laboratory lasting approximately three hours. During this time you will perform a series of cardiovascular exercises in a circuit type fashion. Once again the "Gatorade" type beverage will be provided for your consumption before and during this workout. Lactate and glucose levels will be determined through a simple blood test. A pre-test lasting approximately 15-30 minutes will be administered in order to establish baseline data on the exercise equipment.

The field test will be conducted as follows: 1) consume 6 ml/kg/lean body mass (LBM) of beverage immediately before exercise and 3 ml/kg/LBM during each of the five four minute rest periods 2) participate in a typical two hour lacrosse practice 3) following 120 minutes of practice, consume again 3 ml/kg/LBM of beverage 4) perform a shooting activity in which a teammate will act as a feeder for you to receive a pass, run through a short pattern around cones, and then finish with a shot. Your individual results will be provided for you should you choose to view them. This field test will be repeated within seven days.

The laboratory test will be conducted as follows: 1) make an appointment with the researcher, plan on investing approximately 30 minutes 2) have your weight measured and converted into kilograms 3) perform a series of cardiovascular tests on the bike, upper body ergometer (UBE), treadmill, and rower 4) 75% of your maximal oxygen consumption (max VO_2) will be determined based on tour heart rate and workload on each apparatus 5) make another appointment for the actual lab test (plan on 3 hours) which is comparable to preparation and participation in a typical practice 6) consume 6 ml/kg LBM five times during the exercise bout 7) exercises will be performed in a circuit type fashion in which your workload and heart rate will be continuously monitored 8) you will be encouraged to stay within 75% of your max VO_2 9) a staggered start will be administered 10) you will be asked to perform 20 minutes on each apparatus in the following order: bike, UBE, bike, treadmill, bike, rower, bike 11) two tests for anaerobic power will be conducted: a standing broad jump (SBJ) and the Wingate Anaerobic Test (WAT). The WAT involves pedalling the bike in an attempt to achieve as many revolutions as possible within 30 seconds. The workload will be adjusted according to weight. 12) a blood lactate and glucose sample will be taken by a sterile lancet from the dominant index finger 13) a manual dexterity test will be taken to measure reaction time and visual acuity and lastly 13) you will perform the same skills in the gym that was performed on the field.

All individual information will be documented and available for your review should you choose to take advantage. All group information will be available for the head coach's review.

3. Will this hurt?

You will be exercised to the point of exhaustion. Sensations similar to typical varsity lacrosse post practices may be felt (e.g. fatigue, and possibly muscle soreness). This soreness typically subsides within a few days.

A simple blood test will be administered following the exercise bouts. You will feel a quick prick into the skin of the dominant index finger in which a few drops of blood will be taken. Many of you may have experienced this common procedure during a typical physical. As with any blood withdrawal, you will feel a quick and temporary pain sensation. However, as stated earlier, this pain is transient. Similar to any blood withdrawal procedure, there lies the risk of infection. A sterile lancet will be used for each of you to prevent the risk of infection.

4. <u>Need more information:</u>

<u>Contact:</u> Dr. Gary Sforzo, Assoc. Prof., Exercise Science Dept, Hill Center, 274-3359.
Kristen Wood, Graduate Student, Phys. Ed. Dept., Hill Center, office 274-3663 or 257-6923.

5. <u>Withdrawal from study:</u>

You will be free to withdraw from the study at any time. Your academic or varsity lacrosse status will in no way be affected by your participation or non-participation in this study. If you choose not to participate, you will be exempt from all testing.

6. <u>Will the results be maintained in confidence?</u>

You will not be identified by name, initials or any other means during the interpretation and publication of these data. All data will only be presented in group form. Personal information will not be shared with the head coach or any other individuals you so request.

7. I have read the above, understand its contents and agree to participate in the study. I am 18 years of age or older.

SIGNATURE DATE

Appendix B

CYCLE GRADED EXERCISE TEST PROTOCOL

1. 15 minutes after subject arrived in laboratory and sat down, resting heart rate was recorded.

2. Subject was asked to sit on cycle seat to determine appropriate height. Measurement was recorded for laboratory testing.

3. The cycling revolutions per minute (RPM) was set at 50 for all subjects.

4. Subjects started workload at .5 kiloponds (kp) unless she felt this was too easy, in which case subject started at 1.5 kp.

5. Subject pedalled for one minute at each stage.

6. Workload increased .5 kp every minute.

7. Heart rate was recorded at the end of each minute.

8. Procedure continued until subject was unable to maintain workload for one minute.

9. Upon completion of cycling, maximal heart rate (MHR) was recorded.

10. 80% of MHR was determined. The workload and rpm at 80% MHR were used for future laboratory testing.

Appendix C

UPPER BODY ERGOMETER GRADED EXERCISE TEST PROTOCOL

1. Resting heart rate (RHR) was recorded prior to exercise.

2. All subjects began with a crank speed of 60 and load of kilopond meters per minute (kpm) of 400.

3. Each stage lasted one minute.

4. At the conclusion of each minute, heart rate was recorded.

5. At the end of each stage, kpm was increased by 100 unless subject could not maintain the workload, then crank speed was increased to 90 and workload remained the same.

6. When subject could not continue protocol, exercise ceased and MHR was taken.

7. 80% of MHR was determined. Workload and crank speed used at 80% MHR was used for future laboratory testing.

Appendix D

WINGATE ANAEROBIC TEST PROTOCOL

1. Test procedure was read to each subject to ensure consistency.

2. Subject sat on cycle to check for appropriate seat height which was recorded for future.

3. Subject began pedalling at which time the workload was gradually increased from zero to the subject's predetermined submaximal exercise point.

4. Subject was then given the command "go" and was instructed to pedal as fast as possible for a 30 second (s) duration.

5. At the end of the 30 s time period, subject was then given the command "relax" and was asked to continue to pedal slowly for approximately 15 s.

6. Subject was then instructed to get off the cycle.

7. Velocity, force and power were recorded every 5 s via a computerized program connected to the cycle. Power was further broken down to determine average and peak power output.

Appendix E

REACTION TIME AND SPEED OF MOVEMENT PROTOCOL

1. A statement explaining the procedure for testing was read to each subject so as to maintain consistency. The Dekan Timing Device Automatic Performance Analyzer was used to determine reaction time and speed of movement.

2. Subject was allowed to practice until she felt comfortable with the procedure.

3. Subject placed hand on a sensor pad. Upon a positive verbal reply to the command "ready", researcher pressed a delay start button. Amount of delay was predetermined by the researcher and kept constant for all subjects.

4. Upon seeing the light, subject was instructed to move her hand from one sensor to another, the latter of which stopped the timer. The time it took the subject to react to the light (reaction time) as well as the time it took the subject to hit the sensor (speed of movement) was recorded.

5. The length of time between the "ready" signal and the stimulus were randomly varied to keep the subject from prematurely hitting the sensor prior to the actual

light being activated.

6. During baseline testing, subjects performed 100 trials. During laboratory testing, subjects were allowed to practice 8-10 trials and then performed 20 trials under both testing conditions.

7. Five control trials were instituted within the 20 trials to prevent the subject from prematurely moving prior to the visual stimulus.

8. Speed delay for the light were 1.0, 1.5, 2.0 and 2.5 seconds.

9. A table of random numbers was used to select the order of the speed used.

10. If subject reacted before the light appeared, a statement was read to the subject reminding her about the procedure.

Appendix F

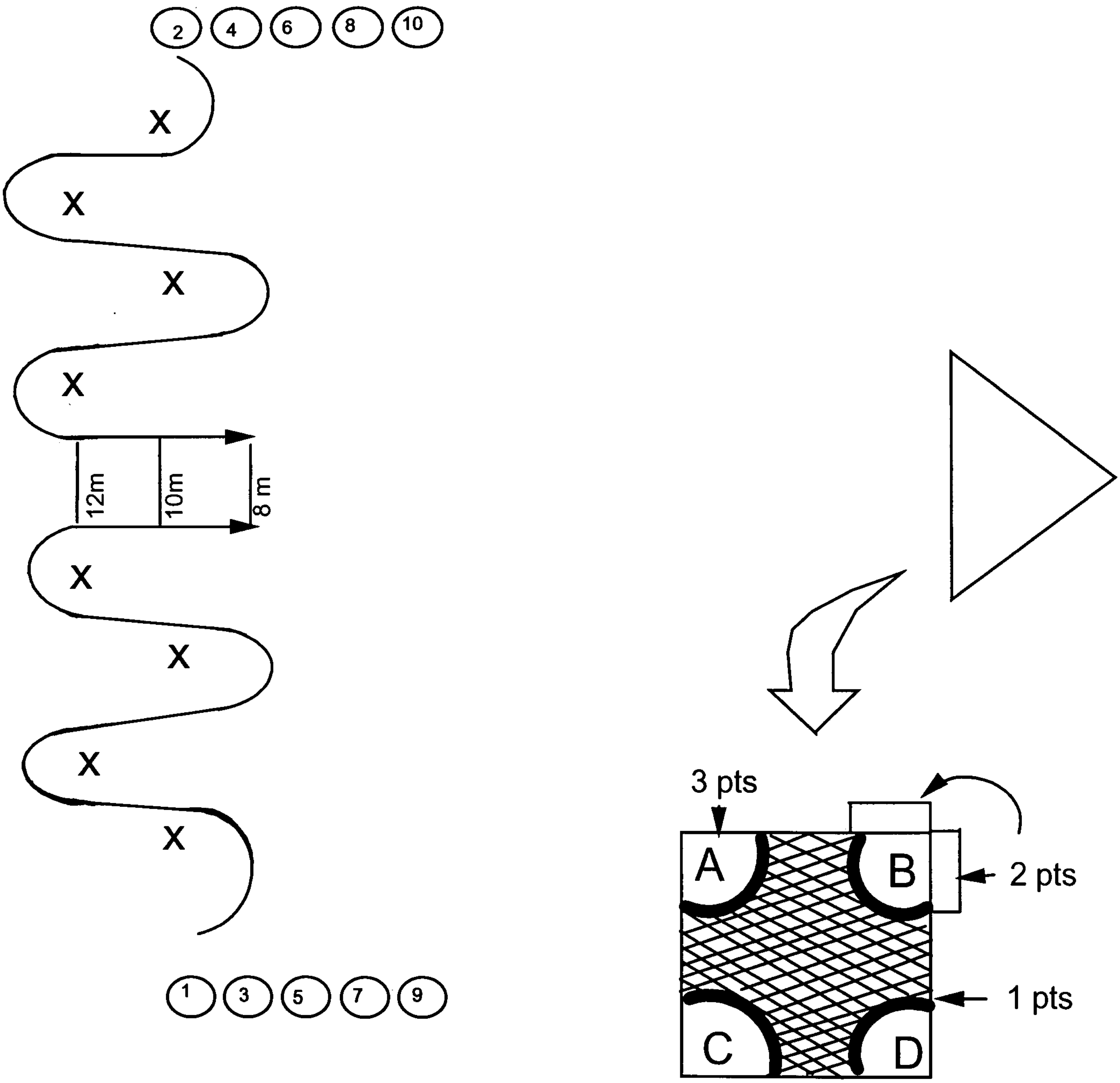
REACTION TIME AND SPEED OF MOVEMENT

SPEEDS AND ORDER

Trial Number	Speed
1	1
2	5
3	4
4	5
5	2
6	5
7	4
8	5
9	1
10	1
11	1
12	2
13	2
14	4
15	5
16	2
17	4
18	3
19	3
20	4

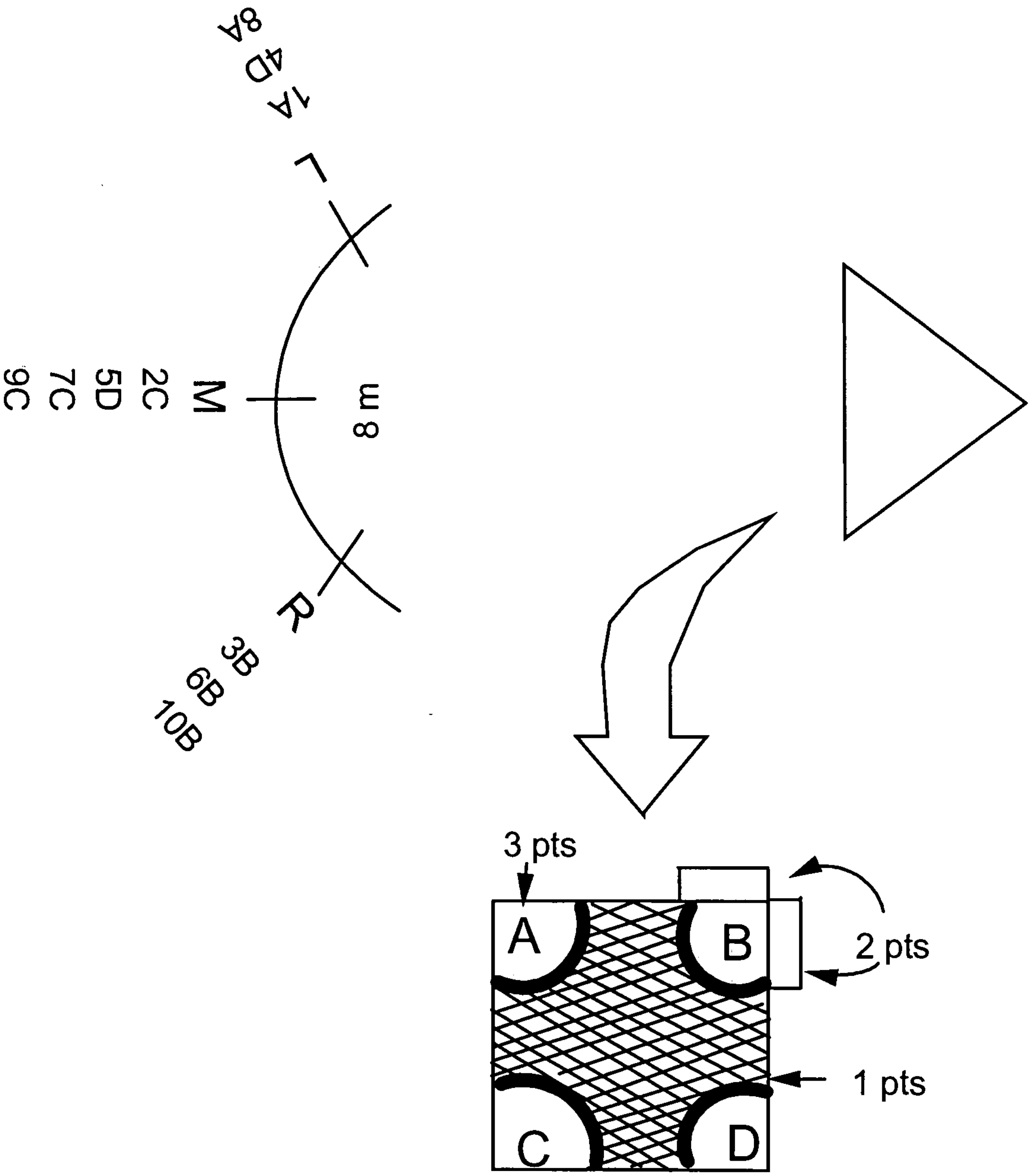
Speed	Seconds
1	1.0
2	1.5
3	2.0
4	2.5
5	Catch Trial (No light appears)

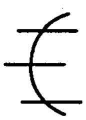
Appendix G
Shooting Drill A



△	Goal
X	Cones
◯	Ball
A - D	3 points
Pipe	2 points
Net	1 point

Appendix H
Shooting Drill B



 8 m mark with hash marks every 1 - 5 m

L M R left, middle and right hash marks - Indicates location of designated shot
A - D 3 points
Pipe 2 points
Net 1 point
Order of shots: 1A, 2C, 3B, 4D, 5D, 6B, 7C, 8A, 9C, 10B

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