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Hydrating with Coconut Water, Water or Gatorade® Results in Similar Basketball Fitness & Skill Performance During a Simulated Basketball Game

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Abstract

Coconut Water (CW), which contains a high amount of the micronutrient potassium (K^+) and almost half the carbohydrate (CHO) as mainstream sports beverages, has the potential to serve as a hydration beverage for athletes who engage in intermittent, high intensity exercise, like basketball. However, no studies to date have investigated this phenomenon. The purpose of this study was to assess basketball specific performance (skill and fitness components) of university varsity basketball student-athletes during a simulated game while hydrating with three experimental treatments: water (W), CW, and Gatorade[®] (G). One male and five female varsity basketball athletes (n=6) each completed three 40-min, on-court, simulated basketball competitions while hydrating with each of the three beverages of interest. For almost all measures of basketball skills: Field Goals Made (FGM), Field Goals Attempted (FGA), Field Goal Percentage (FGP), Dribbling Performance (DP) and fitness: Total Distance (TD), Mean Sprint Time (MS), Sprint Decrement (SD), Mean Circuit Time (MC), Circuit Decrement (CD), etc. there were no significant treatment differences; however, while the athletes hydrated with CW, FGA was greater than W and G ($P=0.006$) in the second quarter. This did translate into more FGM but did not reach statistical significance. More CW research is needed, especially with athletes who engage in intermittent, high intensity exercise, but the present data suggest that hydrating with either CW, W, or G during a simulated basketball game results in similar fitness and basketball skill performance.

Keywords

Potassium, Intermittent High Intensity Exercise, Team Sports, Basketball Specific Skill Test, Basketball Exercise Simulation Test, Carbohydrate, Electrolytes, Sports Drink

Summary for Lay Audience

Coconut Water (CW), which contains a high amount of the micronutrient potassium (K^+) and almost half of the carbohydrate (CHO) of mainstream sports drinks could be a hydration beverage for athletes who engage in team sports, like basketball. However, no studies to date have investigated this. The purpose of this study was to assess basketball specific performance (skill and fitness) of university varsity basketball student-athletes during a simulated game while hydrating with three treatments: water (W), CW, and Gatorade[®](G). One male and five female varsity basketball athletes (n=6) each completed three 40-min, on-court, simulated basketball competitions while hydrating with each of the three beverages of interest. For almost all measures of basketball skills: Field Goals Made (FGM), Field Goals Attempted (FGA), Field Goal Percentage (FGP), Dribbling Performance (DP) and fitness: Total Distance (TD), Mean Sprint Time (MS), Sprint Decrement (SD), Mean Circuit Time (MC), Circuit Decrement (CD), etc. there were no significant treatment differences; however, while the athletes hydrated with CW, FGA was greater than W and G ($P=0.006$) in the second quarter. This did translate into more FGM but did not reach statistical significance. More CW research is needed, especially with athletes who engage in team sports, but the present data suggest that hydrating with either CW, W, or G during a simulated basketball game results in similar fitness and basketball skill performance.

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“Robert W. Woodruff, a prominent business leader of a former time, toured the United States giving a lecture which he entitled “A Capsule Course in Human Relations.” In his message, he said that the two most important words in the English language are these: “Thank you.” *Gracias, danke, merci*—whatever language is spoken, “thank you” frequently expressed will cheer your spirit, broaden your friendships, and lift your lives to a higher pathway as you journey toward perfection. There is a simplicity—even a sincerity—when “thank you” is spoken.” – President Thomas S. Monson (Think to Thank, October 1998).

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List of Abbreviations

- (ACSM) American College of Sports Medicine
- (ADP) Adenosine Diphosphate
- (AHA) American Health Association
- (AI) Adequate Intake
- (ATP) Adenosine Triphosphate
- (BEST) Basketball Exercise Simulation Test
- (BSST) Basketball Specific Skills Test
- (CCHS) Canadian Community Health Survey
- (CDRR) Chronic Disease Risk Reduction Intake
- (CD) Circuit Decrement
- (CHO) Carbohydrate
- (CW) Coconut Water
- (DP) Dribble Performance
- (FDA) Food and Drug Administration
- (FGA) Field Goals Attempted
- (FGM) Field Goals Made
- (FGP) Field Goal Percentage
- (FBT) Final Body Temperature
- (G) Gatorade®
- (IBT) Initial Body Temperature
- (K⁺) Potassium
- (MC) Mean Circuit Completion Time

(MS) Mean Sprint Time

(Mg⁺⁺) Magnesium

(NASEM) National Academies of Science, Engineering and Medicine

(Na⁺) Sodium

(NHANES) National Health and Nutrition Examination Survey

(PEP) Phosphoenolpyruvate

(PK) Pyruvate Kinase

(RPE) Borg's Ratings of Perceived Exertion

(SD) Sprint Decrement

(SDR) Sports Drink

(SW) Sweat Rate

(TD) Total Distance

(US) United States of America

(USDA) United States Drug Administration

(W) Water

1.0 Introduction

Coconut water (CW) is a beverage with the potential to serve as a hydration option for athletes. However, to date hydration research on CW is rare (Prades et al., 2012). Despite this, there is some evidence that CW is an effective hydration option during exercise (Saat et al., 2002; Pérez-Idárraga and Aragón-Vargas, 2014; Leishman, 2015). Further, during World War II in the South Pacific, CW was used successfully as an intravenous fluid for both soldiers and civilians whenever saline was in short supply (Campbell-Falck et al., 2000; Pummer et al., 2001).

CW possesses a unique mixture of macro- and micronutrients (Young et al., 1995). Many agree that potassium (K^+) is the main mineral element in CW (Prades et al., 2012). Of course, K^+ is an essential micronutrient that humans rely upon for survival. Despite this, nutritional trends show that North Americans often have difficulty meeting their K^+ requirements. In fact, typically <2% of US adults consume $\geq 4700 \text{ mg } K^+ \cdot d^{-1}$ (i.e., met recommendations for K^+) (Cogswell et al., 2012). The observed current low K^+ intake is even more striking when compared with that of our distant ancestors, who likely consumed very large amounts of dietary K^+ regularly ($\sim 15,000 \text{ mg} \cdot d^{-1}$, Palmer and Clegg, 2016). Furthermore, dietary K^+ is obtained predominately from fruit and vegetable intake (Tanase et al., 2011), which explains in part why these foods are recommended as part of a healthy diet.

During exercise, most athletes consume sports drinks (SDR) that contain 6 to 8% carbohydrate (CHO) (Sawka et al., 2007). These SDR, such as Gatorade[®] (G) and Powerade[®], also have a large amount of sodium (Na^+) compared to nutritional recommendations. Moreover, it is important to note that SDR contain very low amounts of K^+ (Shirreffs et al., 2007).

Athletes in endurance sports of relatively long duration, i.e., marathon runners, clearly benefit from ingesting CHO during exercise because of the well-established possibility of exhausting CHO stores during a single exercise bout (Tsintzas & Williams, 1998). In contrast, athletes who engage in team sports, which involve less prolonged but intermittent, high intensity exercise should focus more on hydration rather than CHO supply due to the non-glycogen depleting nature of many of these activities (Too et al., 2012). In other words, CHO intake during exercise

is not as critical to maintain performance in intermittent, high intensity exercise, assuming one's pre-event CHO intake is sufficient.

In recent years, SDR consumption has tripled (4% to 12%) among adolescents while soft drink consumption has declined (Han & Powell, 2013). Although clearly a sugar sweetened beverage with many of the same negative health consequences of soft drinks apparently, SDR are perceived differently by many. This raises questions about the accuracy of this perception as well as whether sports drinks are even the best rehydration beverage for athletes. For example, the composition of CW suggests that it has the potential to rehydrate athletes sufficiently with almost half of the CHO vs SDR, much less Na^+ , and much more K^+ but little is known about how it affects exercise performance. To date, there have only been two studies that have measured performance while hydrating with CW and unfortunately, both of these studies contain methodological flaws (Kalman et al., 2012; Peart et al., 2016). Further, both studies involved endurance exercise, so it is unclear whether their results apply to intense, intermittent exercise activities like those found in basketball.

Furthermore, many basketball performance studies to date have been largely based on non-specific basketball measures, such as: anthropometric measures (hand size & wingspan) (Haywood, 1978; Bale, 1991), anaerobic power (Wingate) tests (Scanlan et al., 2011), agility tests, change of direction tests, sprint tests, vertical jump tests (Ziv & Lidor, 2010), and grip strength tests (Bale, 1991) to name a few. To our knowledge, there are currently no reliable basketball-specific skill tests in the literature.

Since mainstream SDR today contain an abundance of CHO (6-8%) and a sizeable amount of Na^+ , there may be room for improvement and advancement. CW has almost half the CHO content of G, a lower amount of Na^+ and a high amount of K^+ . Should exercise performance not be compromised by hydrating with a beverage with lower CHO content, CW may serve as a suitable option for basketball players to hydrate with and increase their daily K^+ intake.

The present study is the first to measure performance (fitness and skills) during intermittent, high-intensity exercise, specifically varsity basketball competition while hydrating with CW,

Water (W), and/or G. It was hypothesized that basketball performance would be similar for participants while hydrating with CW and G and that both CW and G would be better than W.

2.0 Literature Review

2.1 Hydration and Exercise

Drinking during exercise is designed to prevent excessive dehydration (>2% body mass loss from a water deficit) and the associated excessive changes in electrolyte balance because they can compromise both exercise performance and health (Sawka et al., 2007). Typically, trained athletes have greater sweat rates (SW) than do sedentary individuals because their regular exercise training causes thermoregulatory adaptations (Armstrong et al., 1987). Further, trained athletes will start sweating sooner during exercise as body temperatures begins to increase and thus they have a greater potential for dehydration. Of course, the advantage is that trained athletes have a more effective mechanism for controlling body temperature during exercise. Moreover, SW can vary widely among individuals and it is not uncommon for physically active adults in hot and/or humid environments to lose several liters of water per hour through sweating (Murray, 2007). In fact, SW in excess of $2.5 \text{ L}\cdot\text{h}^{-1}$ have been observed in some athletes (Dunford and Doyle, Section 7.3, 2017). It is well known that consuming beverages containing electrolytes and CHO during exercise can provide benefits over water (W) alone at least when the activity is prolonged. If sufficient beverages are consumed with meals and a protracted recovery period (8-12 h) has elapsed since the previous exercise session, most can maintain water balance (euhydration). However, if an individual has experienced substantial fluid deficits and has not had adequate time or fluids/electrolytes intake to re-establish euhydration, then an aggressive pre-hydration program may be merited. The pre-hydration program should be initiated at least several hours before the activity and can help ensure that any previously incurred fluid-electrolyte deficit is corrected prior to initiating the exercise task (Sawka et al., 2007). Adequate hydration is essential or prolonged exercise could be life threatening, especially in hot, humid environments (Murray, 2007).

The preferred hydration fluid temperature is often between 15 and 21°C, but this and flavor preference vary greatly between individuals and across cultures (Sawka et al., 2007). Therefore,

it is critical that individuals develop customized fluid replacement programs that prevent excessive dehydration (>2% body mass reductions) or both performance and health could be compromised. Consumption of beverages containing electrolytes and CHO can help maintain fluid-electrolyte balance as well as exercise fuel supply. As mentioned, physical exercise can elicit high SW and substantial water and electrolyte losses, particularly in warm-hot, humid weather. If sweat fluid and electrolyte losses are not replaced, then the individual will dehydrate quickly during physical activity. Excessive dehydration also reduces exercise performance and increases the risk of exertional heat illness (Sawka et al., 2007). The individualized plan for fluid and electrolyte intake before, during, and after exercise under normal training conditions will need to be adjusted to reflect changing environmental conditions, such as increasing temperature/humidity or the stress of exercise intensity (Murray, 2007). Daily weight loss or gain over the course of a single workout can be used to assess fluid loss, and therefore hydration status, with reasonable accuracy (Cheuvront et al., 2010). One liter of water weighs 1 kg (2.2 lb) so if an athlete completes a hard workout lasting 1 hour and loses 2 kg (4.4 lb) of body mass, it can be assumed that ~2 L of fluid have been lost ($2 \text{ kg} \times 1 \text{ L} \cdot \text{kg}^{-1}$).

Hydration guidelines have been developed to minimize performance and health risks of exercise dehydration but it is important to appreciate that these have been designed for marathon runners primarily rather than for intermittent team sport athletes like basketball players (Dunford and Doyle, Section 7.4, 2017). Although rehydration intake should depend on the individual, a common rule of thumb is to consume ~5-10 mL•kg⁻¹ of fluid in a 2-4 h timeframe prior to engaging in exercise (Thomas et al., 2016; Sawka et al., 2007) but this may be a little low for excessive sweaters. During exercise, the American College of Sports Medicine (ACSM) recommends ~250 mL•15 min⁻¹ (Sawka et al., 2007). Individual trial and error during exercise training can help athletes determine the most appropriate fluid and electrolyte intake before and during competition (Dunford and Doyle, Chapter 7, Summary, 2017).

2.2 Carbohydrate Concentration in a Sports Drink (SDR)

The greatest rates of CHO delivery are achieved with a mixture of sugars (e.g., glucose, sucrose, fructose, maltodextrine) (Sawka et al., 2007). For example, to achieve a CHO intake sufficient

to sustain performance, an individual could ingest one-half to one liter of a conventional SDR each hour (assuming 6-8 % CHO, which would provide 30-80 $\text{g}\cdot\text{h}^{-1}$ of CHO) along with sufficient water to avoid excessive dehydration (Sawka et al., 2007). If both fluid replacement and CHO delivery are going to be met with a single beverage, the CHO concentration should not exceed 6-8 %, because highly concentrated simple sugar beverages reduce gastric emptying (Sawka et al., 2007) and may cause gastrointestinal distress. This latter phenomenon is well known for glucose and depends on the osmolality of the drink. At 6-8% sugar concentrations, 1000 mL would contain 60 to 80 g of CHO. Water is able to move between cellular compartments due to the nature of semi-permeable cell membranes. Moreover, the direction of the water movement is determined by the solute concentration that will either draw fluid into the cell or force it out from the cell. SDR that contain >6-8% simple CHO concentration will draw water into the gastrointestinal tract from the blood causing reduced water absorption, excessive dehydration, and often diarrhea. Of course, any form of gastrointestinal distress is unwanted by the performing athlete during exercise. Thus, it is important to supply the athlete with sufficient fluid and CHO, while not supplying too much.

2.3 Sports Drinks & Exercise

Athletes in sports of relatively long duration, for example, marathon running, benefit the most from ingesting CHO during exercise because body CHO stores may become depleted during the race (Tsintzas & Williams, 1998). Assuming sufficient daily CHO intake ($>5\text{g}\cdot\text{kg body mass}^{-1}$), athletes who engage in exercise activities lasting less than ~60 min are unlikely to need to consume CHO during the activity because body CHO stores are sufficient (Dunford and Doyle, Section 7.3, 2017). Consequently, during exercise lasting less than ~1 h, fluid replacement for sweat loss is more important. Further, for these shorter exercise durations, water (W) works well as a fluid replacement beverage because electrolyte losses are modest. The duration of the activity is also within the range in which endogenous CHO (muscle and liver glycogen) stores are not likely to be depleted, so the inclusion of CHO in the beverage for exercise of this duration is likely not a necessity. However, if an athlete does choose to consume beverages that contain CHO and electrolytes, they are not likely to pose any problems especially if the athlete is

accustomed to these beverages and does not consume excessive amounts (Dunford and Doyle, Section 7.3, 2017).

However, sport beverages and energy drinks fall along the sweetened-beverage continuum that runs from flavoured water to highly concentrated CHO solutions. Many of these drinks contain only sugars and a small amount of electrolytes, i.e., have low nutrient density but can be a significant source of excess energy so water is sometimes a better choice because it does not contain energy. Further, some athletes consume too much added sugar daily and need to be cautious about excessive intake from sports beverages (Dunford and Doyle, Section 7.4, 2017). Phillips et al. (2012) conducted a study examining variable-speed shuttle running while hydrating with three different CHO beverages (2, 6 and 10% CHO). They found that endurance capacity while ingesting the 6% CHO trial was significantly greater (34%) than on the 10% CHO trial but there were no sprint performance differences between the 2, 6 and 10 % CHO trials (Phillips et al., 2012). Furthermore, there was even a trend for the performances to be better on the 2% than on the 10% CHO trial suggesting the importance of fluid over CHO when the exercise is intense but not prolonged (Phillips et al., 2012).

2.4 Sports Drinks Consumption Statistics

Among adolescents, it has been reported that over 10% of the total daily energy consumed comes from soda and fruit drinks alone (West et al., 2006, Troiano et al., 2000, Forshee & Storey, 2003). More recently, the prevalence of soda consumption has decreased, whereas sports/energy drink consumption tripled (4% to 12%) among adolescents (Han & Powell, 2013). These drinks often contain other ingredients besides sugar, such as artificial sweeteners, artificial flavours, artificial colours, etc. which may be problematic from a health perspective (Rogers, 2005). Further, sugar sweetened beverages can also have a detrimental effect on tooth health. In one study, researchers found that tooth enamel dissolution occurred in all of the tested sweetened beverages, with far greater damage occurring in flavored and energy drinks than previously noted for water or cola drinks. Non-cola drinks, commercial lemonades, and energy/SDR showed the most aggressive dissolution effect on dental enamel (Rogers, 2005; Milosevic et al., 1997).

2.5 Coconut Water (CW)

The coconut (*Cocos nucifera*) is one of the oldest known tropical crops and because of its many uses the coconut tree has been called the “Tree of Life” (Chauhan et al., 2014). CW (coconut liquid endosperm), with its many applications, is one of the world's most versatile natural products. It is consumed worldwide and has even been referred to as “mother nature’s sports drink”. The edible part of the coconut (coconut meat and CW) is the endosperm tissue. Endosperm tissues undergo one of three main modes of development (nuclear, cellular and helobial modes) and the development of coconut endosperm belongs to the nuclear mode. Initially, the endosperm is a liquid containing free nuclei generated by a process, in which the primary endosperm nucleus undergoes several cycles of division without cytokinesis (the process in which the cytoplasm of a single eukaryotic cell is divided to form two daughter cells). Cytokinesis then occurs, progressing from the periphery towards the center, thus forming the cellular endosperm layer. At first, the cellular endosperm is translucent and jelly-like, but it later hardens at maturity to become white flesh (coconut meat). Unlike the endosperms of other plants (e.g., wheat and corn), the cellularization process in a coconut fruit does not fill up the entire embryo sac cavity, but instead leaves the cavity solution-filled. This solution is commonly known as CW and it is of cytoplasmic origin (Chauhan et al., 2014). Nutrients from CW are obtained from the seed apoplasm (surrounding cell wall) and are transported symplasmically (through plasmodesmata, which is the connection between cytoplasm of adjacent cells) into the endosperm. CW should not be confused with coconut milk, although some studies have used the two terms interchangeably. The aqueous part of the coconut endosperm is termed CW, whereas coconut milk, also known as “santan” in Malaysia and Indonesia, and “gata” in the Philippines, refers to the liquid products obtained by grating the solid endosperm, with or without addition of water (Chauhan et al., 2014). In some parts of the world, CW is served directly as a beverage to quench thirst, while coconut milk is usually used as a food ingredient in various traditional cooking recipes. The main components of coconut milk are water (~50%), fat and protein, whereas CW contains mainly water (~94%) (Chauhan et al., 2014).

2.6 Composition of Coconut Water

Inorganic ions are required for normal cellular function, and are critical for enzyme activation, bone formation, hemoglobin function, gene expression, and macronutrient (amino acids, lipids, and CHO) metabolism. CW contains a variety of inorganic ions and these contribute to its therapeutic value. It also contains easily digested CHO in the form of sugar. The main sugars in CW are sucrose, sorbitol, glucose and fructose, followed by minor sugars including galactose, xylose and mannose. Further, there exists a rich content of mineral ions in CW, especially K^+ and several B vitamins including B1 (Thiamine), B2 (Riboflavin), B3 (Niacin), B5 (Pantothenic Acid), B6 (Pyridoxine), B7 (Biotin) and B9 (Folate). These water-soluble vitamins are required as coenzymes for many metabolic and enzymatic reactions essential for cellular function (Yong et al., 2009). So, CW presents a series of nutritional and therapeutic properties, being a natural, acid and sterile solution, which contains several biologically active components, arginine, alanine, cysteine, serine, ascorbic acid as well as minerals such as calcium (Ca^{++}), magnesium (Mg^{++}), Na^+ , and K^+ (Sandhya & Rajamohan, 2008). K^+ is the main mineral element in CW and several amino acids have a content that is greater than in cow's milk. Differences in mineral composition exist due to the country of its origin. (Khan et al., 2003). The low acidity combined with well-balanced sugar content and isotonic mineral composition makes CW a potential rehydration/sport drink (Haynes et al., 2004; Prades et al., 2012). According to the United Nations Food and Agricultural Organization (FAO) statement (Press Release SAG/84, 2000), "water found inside the young coconut is biologically pure, tasty and full of salts, sugars, and vitamins that are very beneficial for athletes."

2.7 Hydrating with Coconut Water

Although current research on CW is quite rare (Prades et al., 2012), it has potential as a rehydration drink because its basic ion composition could replenish the electrolytes excreted through sweat, such as Na^+ , K^+ , Mg^{++} and Ca^{++} . The concentration of these electrolytes in CW generates an osmotic pressure similar to that observed in blood and it also does not affect hemostasis (plasma coagulation) (Pummer et al., 2001). Further, the mineral composition and sugar content make CW a natural isotonic liquid (Prades et al., 2012). Indeed, CW was used as

an intravenous fluid during WWII when saline was in short supply (Campbell-Falck et al., 2000; Pummer et al., 2001). It appears that the characteristics of CW make it a near ideal rehydrating/refreshing drink for exercising individuals (Prades et al., 2012).

A group of researchers (Saat et al., 2002) discovered that measures of hydration such as blood volume restoration with CW ingestion was not statistically different from a CHO/electrolyte beverage and/or W. Moreover, CW was significantly sweeter, caused less nausea, fullness, no stomach upset, and could be consumed in larger amounts compared with either the CHO/electrolyte beverage or W (Saat et al., 2002). Another study reported that fluid retention was greater for SDR than W, but not vs CW (Pérez-Idárraga and Aragón-Vargas, 2014). Interestingly, a third study found, that the fitter subjects reported feeling more sick throughout the rehydration phase while rehydrating with a SDR compared to the less fit individuals and this was not seen when subjects rehydrated with CW (Leishman, 2015). Finally, a fourth study found that CW was similar in sweetness to SDR but caused less nausea and stomach upset compared to SDR and W (Ismail et al., 2007). Together, these investigations suggest that CW can be at least as good as both W and conventional SDR as a rehydration beverage.

2.8 Hypervolemic Hyponatremia

During prolonged endurance exercise, water intake that is far in excess of fluid lost (primarily through sweat) puts the endurance athlete at risk for a potentially fatal condition, known as hypervolemic hyponatremia, due to low blood Na^+ (Noakes et al., 1985; Armstrong et al., 1993). Low Na^+ concentrations in the extracellular fluid will stimulate the movement of water from the plasma into the intracellular spaces, which ultimately causes the cells to swell. If nerve cells, such as those in the brain, swell too much, they cease to function properly, which can result in symptoms of dizziness, confusion, seizure, coma, and even death (Dunford and Doyle, Section 7.4, 2017). Although rare in shorter events, hypervolemic hyponatremia has been reported in up to 10% of runners in certain ultra-endurance running events and in as many as 29% of triathletes (Speedy et al., 2000). Note that these events involve endurance exercise lasting over 7 hours, often in conditions of high heat and humidity, resulting in significant sweat losses. The physiological mechanisms of this exertional hyponatremia are not completely understood, but the

leading hypothesis is that it is due to a combination of overconsumption of hypotonic fluids, particularly water, and loss of Na^+ through heavy sweating (Hew-Butler et al., 2015). Typically, fluids are classified as hypotonic, isotonic, or hypertonic if they have a concentration of solutes that is less than, the same as, or greater than the concentration of solutes in the cells.

Hypervolemic hyponatremia can also occur in slower marathon runners, who are on the course for 5 or more hours, all the while consuming water or other beverages with a low Na^+ content (Almond et al., 2005). Importantly, the Na^+ content in SDR can be beneficial in preventing hyponatremia. For most athletes who engage in shorter term exercise but still hydrate with SDR, the Na^+ content of the beverage is not a significant concern (Hew-Butler et al., 2015), although the energy content can be. Further, with exercise lasting less than 2 hours, the athlete should pay more attention to fluid replacement to address the water loss through sweating than to Na^+ replacement (Dunford and Doyle, Section 7.4, 2017). Finally, it has even been suggested that the Na^+ excreted in sweat during physical activity offsets a significant fraction of excess dietary Na^+ , and hence may contribute to the health benefits of exercise (Turner and Avolio, 2016).

2.9 Dietary Potassium in North America

K^+ is an extremely important mineral, as indicated by the recent Dietary Guidelines for Americans and the Food and Drug Administration (FDA) designation that K^+ is a “nutrient of public health concern” because of its general under-consumption across the United States (US) population (Palmer and Clegg, 2016). The average dietary intake of K^+ in North America is below the current nutritional recommendations, adequate intake level, (AI) which for K^+ ranges from 2300 to 3400 $\text{mg}\cdot\text{d}^{-1}$ based on sex and stage of life [there is no associated Chronic Disease Risk Reduction Intake (CDRR)] (NASEM, 2019). The observed current low K^+ intake is even more striking when compared with that of our distant ancestors, who consumed very large amounts of dietary K^+ regularly ($\sim 15,000 \text{ mg}\cdot\text{d}^{-1}$, Palmer and Clegg, 2016). This intake exceeds the National Health and Nutrition Examination Survey (NHANES) recommendations by a factor >4 (DeSalvo et al., 2016).

Not only are diets of Western industrialized societies much lower in K^+ intake, but they also differ from prehistoric cultures with respect to Na^+ intake. The daily intake of Na^+ in Western

industrialized societies is about 3 times greater than the daily intake of K^+ on a molar basis, whereas Na^+ intake in primitive cultures was ~ 7 times lower than K^+ intake (Sebastian et al., 2006). The current AI for Na^+ is $1500 \text{ mg}\cdot\text{d}^{-1}$ for people 14 years and older and the age-associated CDRR is $2300 \text{ mg}\cdot\text{d}^{-1}$ (NASEM, 2019). It is worth noting that the AI for K^+ is almost 1.5 times the CDRR of Na^+ , implying that we as humans need K^+ not Na^+ . The changes in K^+ and Na^+ intake over time reflects a shift from traditional plant-based diets high in K^+ and low in Na^+ (characterized by fruits, leafy greens, roots, and tubers) to processed foods high in Na^+ and low in K^+ (Young et al., 1995). Low daily dietary K^+ intakes in both Canada and the USA, are reflections of low daily fruit and vegetable intakes and the high intakes of processed foods. It is well known that this is because food processing results in substantial K^+ losses.

The NHANES from 2003-2008 reveals more information about K^+ and Na^+ intakes. It used 24-h dietary recalls from 12,581 adults aged ≥ 20 years. Overall, 99.4% (95% CI: 99.3%, 99.5%) of US adults consumed more Na^+ daily than recommended by the American Health Association (AHA) ($<1500 \text{ mg}$), and 90.7% (89.6%, 91.8%) consumed more than the CDRR (2300 mg). Overall, $<2\%$ of US adults consumed $\geq 4700 \text{ mg } K^+\cdot\text{d}^{-1}$ (i.e., met recommendations for K^+) (Cogswell et al., 2012). Regardless of recommendations or sociodemographic or health characteristics, it is clear that the vast majority of North American adults consume too much Na^+ and too little K^+ .

The formerly known Institute of Medicine, now National Academies of Science, Engineering and Medicine (NASEM), and the US Department of Health and Human Services/United States Drug Administration (USDA) recommends that Americans increase consumption of K^+ by increasing intake of K^+ -containing fruit and vegetables, lean meats, and milk (Tanase et al., 2011). The Canadian Community Health Survey (CCHS) from 2015 revealed that Canadian females ages 19-30 have a mean daily Na^+ intake of 2374mg and a mean daily K^+ intake of 2354mg. The 2015 CCHS also revealed that Canadian males ages 19-30 have a mean daily Na^+ intake of 3608mg and a mean daily K^+ intake of 3040mg. Both of the recorded Na^+ values are above the CDRR.

2.10 Potassium Supplements

K^+ supplements are often considered a convenient method of increasing K^+ intake; however, this method can bring some concerning or even fatal consequences. For example, gastrointestinal symptoms (discomfort, mucosal lesions and sometimes ulcerations) have been seen in healthy individuals taking some forms of K^+ supplements (Argawal et al., 1994). Self-prescribed or “over the counter” K^+ supplements are not recommended because of the potential for hyperkalemia (Dunford and Doyle, Section 9.2, 2017). Potassium chloride has been recommended by medical professionals to treat low K^+ content but its use is not without risk as it is also the typical drug used for executions administered through lethal injection (Wetherton et al., 2003). A massive dose of K^+ will cause a severe case of acute hyperkalemia which can result in cardiac arrest. If prevention of hyperkalemia is the goal, as it should be, indiscriminate use of K^+ supplements as well as K^+ -sparing diuretics needs to be avoided (Ponce et al., 1985). It has even been suggested that K^+ therapy has cost more lives than it has saved (Burchell, 1973). Typically, vitamin and mineral supplements are not recommended routinely for athletes unless known deficiencies exist (Ryder et al., 2005). Supplement therapy has always been dangerous because it is easy for people to overdose with a particular nutrient. Finally, hypokalemia can also occur because of the presence of underlying disease (Dunford and Doyle, Section 7.3, 2017).

2.11 Potassium Absorption and Secretion

It is well known that K^+ is the major intracellular cation and Na^+ is the major extracellular cation. Of the $\sim 90 \text{ mEq}\cdot\text{d}^{-1}$ of K^+ in a typical diet, $\sim 90\%$ (81 mEq) is absorbed and an equivalent amount of K^+ is excreted in urine. Further, normal fecal K^+ excretion is $\sim 9 \text{ mEq}\cdot\text{d}^{-1}$. Therefore, K^+ is not stored in the body in significant quantities. The vast majority of K^+ absorption occurs in the small intestine and the contribution of the normal colon to net K^+ absorption is trivial (Agarwal et al., 1994). K^+ is absorbed mainly by passive mechanisms; the rectum and the sigmoid colon have the capacity to actively secrete K^+ , but the quantitative and physiological significance of this active secretion is uncertain (Agarwal et al., 1994). Extracellular K^+ makes up only about 2% of the total body K^+ stores. The majority of body K^+ is distributed in the intracellular space

(about 80% is in the skeletal muscle) and movement of K^+ in and out of skeletal muscle plays a pivotal role in extracellular K^+ homeostasis (Li et al., 2017). Of the ~90% absorbed K^+ , 80% is taken up immediately (within 90 minutes) by cells and 90% of that is by skeletal muscle.

K^+ movement occurs between cells through tight junctions driven by the electrochemical gradient. K^+ concentration in the lumen of the small intestine is greater than the concentration of K^+ in the extracellular fluid, therefore allowing K^+ to travel from an area of high concentration to low concentration. It is well established that once in the extracellular fluid, K^+ relies on the Na^+/K^+ ATPase pump to actively transport it from the extracellular fluid into the cell. It is also well known that this pump maintains and re-establishes the resting membrane potential (-40 mV to -75 mV) in cells following and prior to an incoming action potential. There are cellular proteins, phosphate groups, and nucleotides which all possess negative charges (anions) that are fixed inside the cell and cannot pass through the cell membrane. These large negative ions attract positive ions from the extracellular fluid resulting in a net positive charge on the outside surface of the cell membrane and a net negative charge on the inside surface. The resting membrane potential is determined by the permeability of the membrane to different ion species and the difference in ion concentrations between the intra- and extracellular fluids. The resting membrane potential of the cell membrane has an increased permeability for K^+ . The Na^+/K^+ ATPase pump actively pumps 2 K^+ ions into the cell in exchange for 3 Na^+ ions out of the cell (Morth et al., 2007). When the concentration of K^+ increases in the extracellular fluid, the resting membrane potential rises from ~-75 mV to ~-55 mV. Consequently, this results in the cell membrane becoming easier to excite and reach the “all-or-nothing” threshold of ~-40 mV, producing an action potential (Morth et al., 2007).

2.12 Potassium and Carbohydrate Metabolism

K^+ also plays an essential role in CHO metabolism. Pyruvate kinase (PK) catalyzes the final step in glycolysis, producing the second, of two adenosine triphosphate (ATP) molecules generated in the glycolytic pathway. The enzyme converts phosphoenolpyruvate (PEP) and adenosine diphosphate (ADP) to pyruvate and ATP. This reaction is a committed step leading to either anaerobic fermentation or oxidative phosphorylation of pyruvate because pyruvate is at the

crossroads of metabolism. In most cells the reaction is essentially irreversible ($K_{eq} = 10^3$ to 10^4) and is one of the major control points in glycolysis. The regulation of PK is important for controlling the concentration of ATP, GTP and glycolytic intermediates in the cell (Jurica et al., 1998). PK requires monovalent K^+ for its activity (Mattevi et al., 1996). The reaction is essentially irreversible under physiological conditions and is critical for the control of the metabolic flux in the second part of glycolysis. Such a central position in the cellular metabolism is reflected in the regulatory properties of PK (Mattevi et al., 1996). Furthermore, PK catalyzes the transfer of phosphoryl group of PEP to ADP in the presence of two ions of Mg^{++} and one of K^+ . PK has an absolute requirement for K^+ ; its activity with and without K^+ is 250 and $0.02 \mu\text{mol}\cdot\text{min}^{-1}\cdot\text{mg}^{-1}$, respectively. As expected, in 100% water without K^+ , the V_{max} of PK is notably lower than with K^+ (~400-fold), whereas the respective affinity in the absence of K^+ for PEP and ADP- Mg^{++} is about 5- and 6-fold lower than in the presence of K^+ (Oria-Hernandez et al, 2005). These results are consistent with reports that show that K^+ increases the activity and affinity of the enzyme for substrates and Mg^{++} (Oria-Hernandez et al, 2005).

3.0 Methods

3.1 Participants

A total of 30 Canadian varsity basketball players from the men's and women's Western University Varsity Basketball Teams were recruited for this project. Of those 30 individuals, 8 (1 male and 7 female) varsity basketball players began the study ($n = 8$). Two participants were injured in activities outside the study before they were able to complete all of the study procedures. In the end, 6 total (1 male and 5 female) participants completed all 3 treatment conditions ($n = 6$). Oral contraceptive use or time of the menstrual cycle was not controlled. Prior to any testing, the potential risks/discomforts were explained in full and all participants provided written, informed consent of the protocol approved previously by the Office of Research Ethics at Western University. All data collection was collected in the Alumni Hall gym or the Thames Hall gym at Western University.

3.2 Experimental Overview

A single-blind study incorporating a systematically rotated treatment order and a within-subject research design was implemented involving three experimental treatments, water (W), Gatorade® (G), and coconut water (Thai Heritage Coconut Water®) (CW). Each treatment consisted of a 40-minute simulated basketball game. Drink treatment conditions were separated by a washout period of at least a one-week. Briefly, the first participant was assigned randomly to one experimental treatment and thereafter treatments were systematically rotated to avoid order effects. Each participant completed all three treatments and while she/he knew what they were drinking, the investigator did not. The beverage preparation and order assignments were completed by an undergraduate student, who was not otherwise involved in the study. All drinks were given to the participants in five opaque, plastic 1L white sport drink bottles. Drink volume varied depending on body mass and was based on the current ACSM hydration guidelines (range = 0.5-1.0 L•h⁻¹ during exercise) (Sawka et al., 2007). Each participant consumed the same beverage volume across treatments.

Participant selection began with the investigator meeting individually with the Head Coaches of the Western University men's and women's Varsity Basketball Teams and requesting permission to meet with their teams. Then, the investigator met with both teams where all aspects of the study were explained, and contact information forms were distributed to each interested student-athlete. Upon receiving the completed information forms, each participant came to the Exercise Nutrition Research Laboratory where the simulated basketball game (tests and drills) to be used were reviewed and individual measurements (height, mass, etc.) were recorded.

To familiarize the student-athletes fully, each watched videos of the drills they would complete during the game simulation while eating their dinner the evening before the initial treatment data collection session. Further, on the testing days, before any data was collected, each participant was required to complete a walk-through of each drill/test three times without error.

All participants kept dietary records (type and quantity of food and drink) the day prior to their first treatment session in order to consume the same quantity of food at the same times prior to each subsequent condition. No exercise was completed on the day prior to all treatment sessions.

Finally, a standardized CHO and energy dinner ($3 \text{ g}\cdot\text{kg}^{-1}$ CHO, $12 \text{ kcal}\cdot\text{kg}^{-1}$) consisting of spaghetti and tomato sauce with fruit juice was provided at 1800 h on the eve of testing in order to minimize intra- and inter-nutritional status variability (Jeacocke & Burke, 2010) and to control both liver and muscle CHO stores across experimental treatments (Williams & Rollo, 2015). Participants came to the lab following an overnight fast and then consumed the same standardized breakfast prior to each simulated game (details below).

3.3 Measurements

The simulated basketball game consisted of two parts, a test of skill (Basketball Specific Skills Test) and a test of fitness (Basketball Exercise Simulation Test), as described below.

3.3.1 Basketball Specific Skills Test (BSST)

The BSST assesses basketball skill by combining in one test a series of drills used commonly by players in both the National Basketball Association and National Collegiate Athletic Association. Several of the individual drills used were developed by (and named after) Hall of Fame basketball players. None of the drills used were developed for this study, but the combination and sequential order of these drills were.

The BSST included 6 drills (Ray Allen Drill, 5 Star Drill, Steve Nash Drill, 5 Step Combo Drill, a dribbling drill, and Steve Nash Drill a second time) performed on a flat, non-slippery wooden surface in a gym at Western University. Male participants used an approved Ontario University Athletics (OUA) basketball specific to their gender (29.5 inches in circumference) while female participants used an approved OUA basketball specific to their gender (28.5 inches in circumference). Participants gave a maximal effort during each section of the BSST and the same experienced rebounder was used in order to return the ball consistently to the shooter for all drills. The test-retest reliability of the BSST produced an intraclass correlation coefficient (ICC) ranging between 0.84-0.94 for Field Goals Made (FGM), Field Goals Attempted (FGA), Field Goals Percentage (FGP), and Dribbling Performed (DP).

3.3.1.1 Ray Allen Drill (3PT Shots)

Participants begin the BSST with the Ray Allen drill (Figure 1). Starting beside one of the two green cones at the top of the 3-point arc, each student-athlete attempted to make 3-point baskets, alternating between the two green cones, as rapidly as possible. Shots were attempted until 4 total baskets are made. Then, the drill continued, alternating between the two red cones at the wing of the 3-point arc, and then at the two blue cones in the corners. Participants were required to run around the 3-point arc to each cone, i.e., could not cut through the centre area (key). The drill continued for 2 minutes and was scored as the number of baskets attempted and made. Only shots attempted from outside the 3-point arc counted. If the entire circuit was completed with time remaining the participant started over at one of the top two green cones.

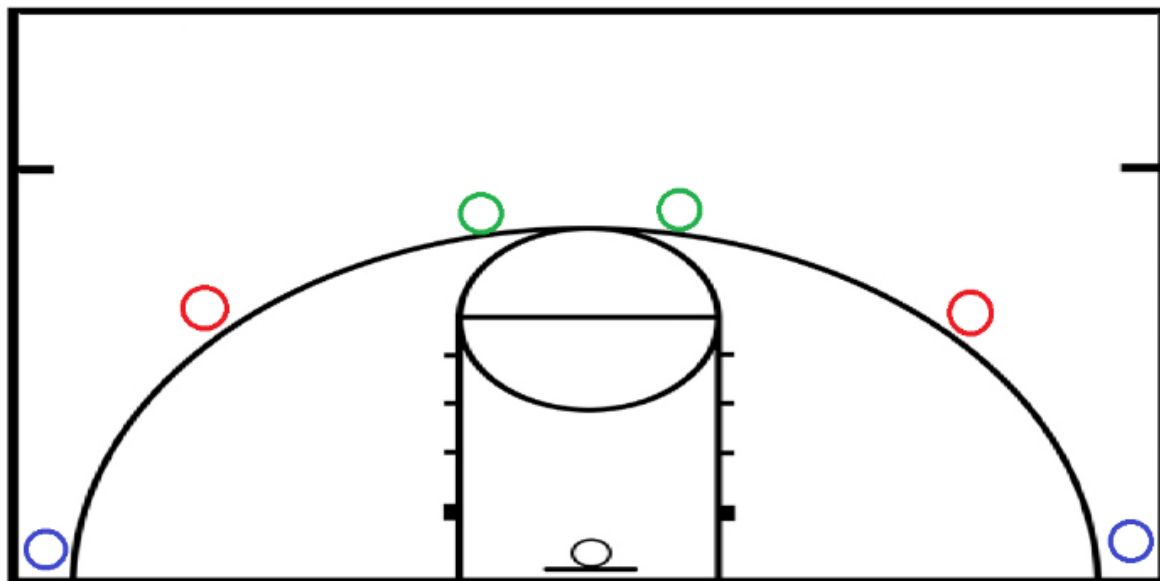


Figure 1. Ray Allen Drill

3.3.1.2 5 Star Drill (Mid-Range Shots)

Next, participants moved as quickly as possible to cone 1 or cone 4 on an adjacent court and continued with the 5-Star drill (Figure 2). This drill involved shooting mid-range shots moving in sequential order (forming a star) from locations indicated by the 5 cones inside the 3-point line. This drill continued for 2 minutes and was scored as the number of baskets attempted and made.

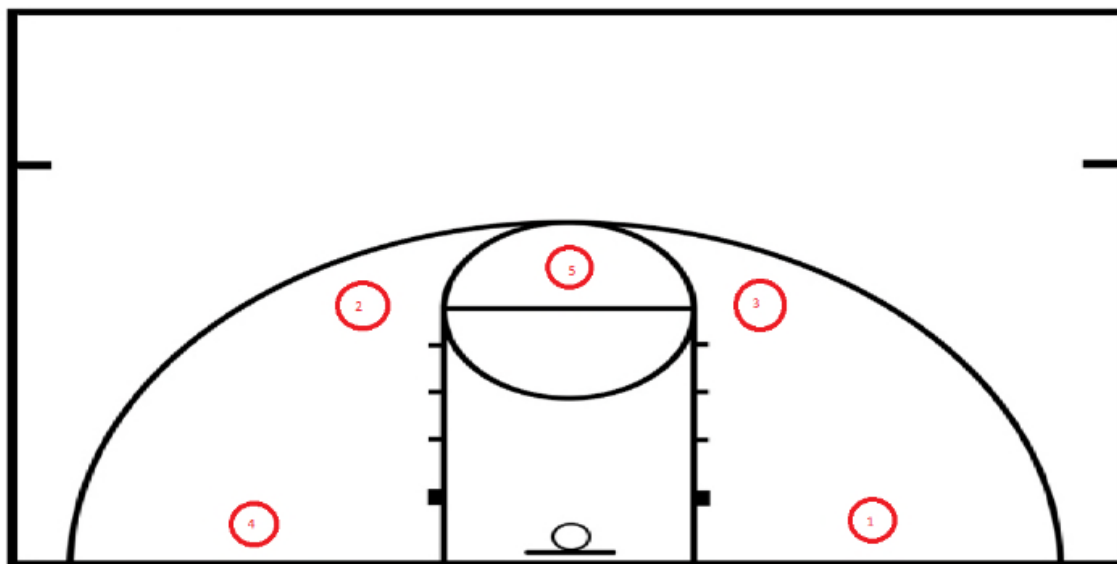


Figure 2. 5 Star Drill

3.3.1.3 Steve Nash Drill (Free Throws)

Then, participants completed a free throw drill, commonly known as the Steve Nash drill (Figure 3). From the free-throw line each individual attempted to make as many free-throws as possible in one minute. The drill was scored as the number of baskets made and attempted.

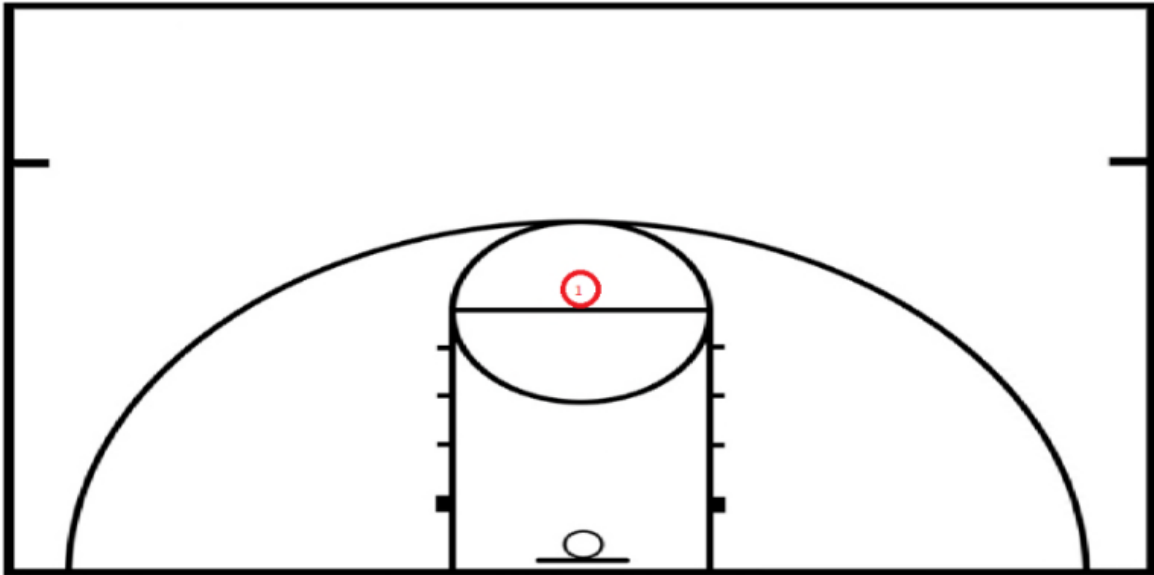


Figure 3. Steve Nash Drill

3.3.1.4 5 Step Combo Drill (MID & 3PT)

Participants then completed the 5-step combo drill which is a combination of 3-point shooting and mid-range shooting from each of the 5 cones (Figure 4). Starting from either cone 1 or 5 (in the corners), participants shot two 3-point shots first, then starting from behind the 3-point line, took one dribble forward to the right using their right hand into the mid-range area and shot. Next, they returned behind the 3-point line and took one dribble forward to their left with their left hand into the mid-range area and shot. Then, they returned behind the same 3-point cone and shot a 3-point shot (total of 5 shots per cone). Next, they progressed as quickly as possible to the other cones in sequence (corner, wing, top, wing, corner) and repeated the same 5 shots. If they completed all the shots within 2 minutes, they started again from the initial cone. The drill was scored as the number of baskets made and attempted in two minutes.

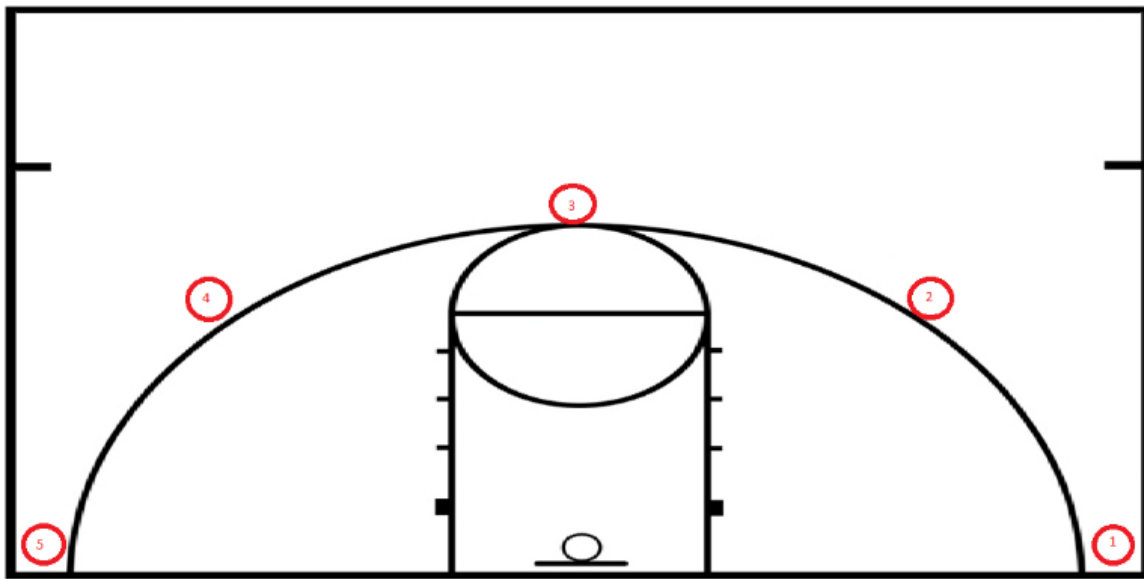


Figure 4. 5 Step Combo Drill

At the completion of the 5 Step Combo Drill, the participants sprinted to a spot within the key and dribbled for 2 minutes in a stationary position performing a prescribed series of dribbles using their dominant hand. This drill involved 25 ground tap dribbles, 25 knee high dribbles, 25 pound and crossover dribbles, 25 pound and between legs dribbles, and 25 pound and behind the back dribbles. If participants completed all the dribbles within 2 minutes, they were instructed to start from the beginning again. This drill was scored as the number of dribbles performed (DP).

Finally, each student-athlete repeated the free throw drill (Steve Nash drill) for 1 minute. The drill was scored as the number of baskets made and attempted. This entire protocol was designed to represent the first quarter of our simulated basketball game. Consequently, it was repeated a second time following a 2-minute rest/recovery period (quarter time intermission).

Both 1st and 2nd quarters of the BSST were video recorded using an iPad. Shots and dribbles were then tallied later that day after the session was completed.

The following measures of performance were determined from the BSST:

- 1) Field Goals Made (FGM) = total shots from the player, from the free-throw line, mid-range area, and three-point line combined that enter the net successfully, expressed as an absolute number
- 2) Field Goals Attempted (FGA) = total shots from the player, from the free-throw line, mid-range area, and three-point line combined that either enter the net or not, expressed as an absolute number
- 3) Field Goal Percentage (FGP) = FGM/FGA , expressed as a percentage
- 4) Dribbles Performed (DP) = total number of dribbles the player was able to perform successfully, expressed as an absolute number

3.3.2 Basketball Exercise Simulation Test (BEST)

The BEST (Scanlan et al., 2012; 2014) includes several activities over a 10-minute time period [distance covered (DC) is 1,438 metres] designed to simulate the movements, distances, and exercise intensities found in one quarter of a basketball game. Each activity (walking, jogging, running, sprinting, low shuffling, i.e., activity characterized by shuffling action of the feet within a defensive stance position at moderate pace, high shuffling, i.e., activity characterized by shuffling action of the feet within a defensive stance position, performed at maximal effort, and jumping) was undertaken during a single 30 second circuit. These activities were performed continuously for 10 minutes (20 circuits) on a basketball court to simulate one quarter of basketball competition. This test was performed twice to simulate basketball-specific fitness during the 3rd and 4th quarters of our simulated basketball game. The BEST was performed on a flat, non-slippery wooden surface in a gym at Western University. Timing gates (Western Engineering Electronic shop, London, CA) were placed at 0, 6m and 61.6m. Each circuit was initiated one foot behind the start line to avoid false triggering of the first timing gate. Participants gave a maximal effort during each section of the BEST. The following measures of performance were calculated from the BEST:

- 1) Mean sprint time (MS) = average time, expressed in seconds, for all the sprints performed.
- 2) Mean circuit completion time (MC) = average time, expressed in seconds, for all circuits completed
- 3) Percent sprint decrement (SD) = $100 \times (total\ sprint\ time / ideal\ sprint\ time) - 100$,

where:

Total sprint time = sum of sprint times from all sprints.

Ideal sprint time = number of sprints x fastest sprint time (Glaister et al., 2008).

- 4) Percent circuit decrement (CD) = $100 \times (total\ circuit\ time / ideal\ circuit\ time) - 100$,

where:

3.4 Experimental Protocol (Figure 6)

Exercise was avoided for 24h prior to testing. On test days, participants reported to the Exercise Nutrition Research Laboratory at 0555 h after an overnight fast following a standardized evening meal (see Figure 6 below for details). Participants were then weighed wearing a set of dry clothing that they did not plan to exercise in. After the weighing, participants were told to change into appropriate clothing (shirt, shorts, socks and shoes) for the basketball drills. Participants wore the same exercise attire each training session. Next, each student-athlete consumed the first treatment beverage (750mL) with a standardized breakfast (toasted bagel with one tablespoon of Nutella[®]). This was the first food/drink intake following the 12-hour overnight fast. After the standardized breakfast had been consumed entirely, the investigator and the participant proceeded to the gym where each participant rested for 25 minutes for digestion/absorption of breakfast. After this rest period, body temperature of each participant was recorded using a digital ear thermometer (Braun, Kronberg, Germany). Participants then underwent a standardized stretching and warm-up protocol and consumed the second treatment beverage (250mL). At 0745 h the participants underwent the first 10 min quarter of the BSST. Then, they rested/recovered during a 2 min break (first intermission) and consumed the third beverage. The 3rd to 5th beverages were relative to each participant's mass, based upon established ACSM guidelines. Next, the participants underwent the second session of the BSST simulating the second quarter of a game. Then, the participants received a 15 min break (halftime) and consumed the fourth beverage. The participants then underwent the first BEST simulating the third quarter of a game, received another 2 min break (second intermission), and consumed the fifth and final beverage. Then, the participants underwent the second BEST (fourth quarter). Following the second BEST, the simulated game was complete. At this time, body temperature and Ratings of Perceived Exertion (RPE), 20-point scale (Appendix C) (Borg, 1973) were recorded. Finally, once sweating had stopped, each student-athlete dried off completely using a towel, changed into the original dry clothes and was reweighed. At this point the first treatment was complete. Participants waited at least one week before completing the next experimental session.

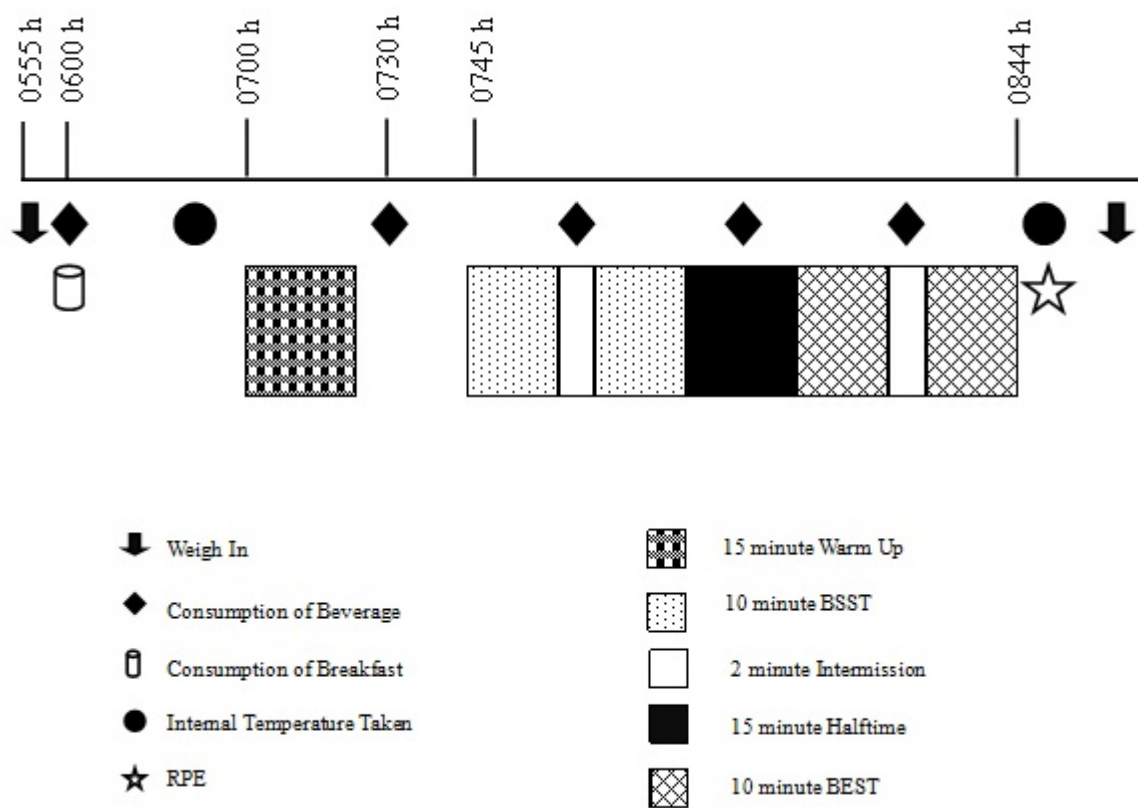


Figure 6. Experimental Protocol

3.5 Secondary Measurements

- 1) Environment conditions (temperature and humidity) in the gyms were measured using a wet/dry thermometer in degrees Celsius (°C). 10 swings of the thermometer was the standardized technique for each measurement to simulate running temperature.
- 2) Body height (without shoes) was measured using a wall-mounted stadiometer and was expressed in meters (m).
- 3) Sweat rate was determined using body mass changes corrected for breakfast and drink intake in minimal, separate, dry clothing, assuming $1\text{kg}\cdot\text{L}^{-1}$.

3.6 Statistical Analysis

Statistical analyses were performed using SigmaPlot for Windows (Version 12.0). A one-way ANOVA with repeated measures was used to analyze the data for all measurements and Tukey's Post Hoc test was used, where necessary. Significance was set at $P \leq 0.05$.

4.0 Results

4.1 Descriptive Statistics Analysis

The physical characteristics of the participants are displayed in Table 1.

Table 1. Participant Characteristics (n=6)

Participant	Age (y)	Position	Height (cm)	Mass (kg)	Gender
1	19	SF	193	93.5	M
2	18	SF	173	75.4	F
3	20	PG	159	72.2	F
4	20	PG	170	65.8	F
5	19	PF	180	78.1	F
6	19	SG	175	64.9	F
mean±SD	19±0.75	N/A	175±11.3	75.0±10.4	N/A

SF=small forward, PG=point guard, SG=shooting guard, M=male, F=female

4.2 Basketball Specific Skills Test (BSST)

There was a significant effect of treatment on field goals attempted (FGA) and post hoc testing indicated that when participants hydrated with CW, FGA was greater ($P<0.05$) in the second quarter than when hydrating with either W or G. There were no significant differences for any other measure, although in both Quarter 1 and 2 Dribbles Performed (DP) tended to be lower for the G treatment ($P<0.15$, Table 2).

Table 2. Basketball Specific Skills Test Measures (Mean \pm SD)

	Quarter 1				Quarter 2			
	FGM (#)	FGA (#)	FGP (%)	DP (#)	FGM (#)	FGA (#)	FGP (%)	DP (#)
W	54 \pm 11	98 \pm 7	55.1 \pm 10.1	178 \pm 31	54 \pm 7	96 \pm 8	56.1 \pm 5.1	177 \pm 35
G	50 \pm 4	97 \pm 7	52.4 \pm 3.7	158 \pm 30 ⁺	52 \pm 11	95 \pm 7	54.6 \pm 9.8	156 \pm 30 ⁺
CW	59 \pm 12	99 \pm 7	58.8 \pm 9.5	168 \pm 34	55 \pm 12	100 \pm 7*	55.3 \pm 10.3	177 \pm 41

W=water, G=Gatorade[®], CW=coconut water, FGM=field goals made, FGA=field goals attempted, FGP=field goal percentage, DP=dribbles performed; * $P=0.006$, ⁺ $P<0.15$

4.3 Basketball Exercise Simulation Test

There were no significant differences for any measures from the BEST, but MC (slower with G) and CD (less with W) in Quarter 3, approached significance. Total distance (m) was exactly the same as all participants completed the maximum possible distance in both the third and fourth quarters (Table 3).

Table 3. Basketball Exercise Simulation Test Measures (Mean±SD)

	Quarter 3					Quarter 4				
	TD (m)	MS (s)	SD (%)	MC (s)	CD (%)	TD (m)	MS (s)	SD (%)	MC (s)	CD (%)
W	1438±0	1.5±0.1	8.2±3	20.9±1.3	3.9±2.0 ⁺	1438±0	1.5±0.1	8.6±2.2	21±1.2	6±1.6
G	1438±0	1.5±0.1	10.5±5.5	21.3±1.5 ⁺	6.4±1.8	1438±0	1.6±0.1	8.8±3.1	21.3±1.6	6±1.6
CW	1438±0	1.5±0.1	13.3±7	20.5±1.5	7.1±4.7	1438±0	1.6±0.1	9.1±5.3	20.8±1.7	5.9±2.5

W=water, G=Gatorade[®], CW=coconut water, TD=total distance, MS=mean sprint time, SD=sprint decrement, MC=mean circuit completion time, CD=circuit decrement; *P<0.05, ⁺P<0.15

4.4 Ratings of Perceived Exertion

There were no treatment differences observed for RPE ($P=0.173$, Table 4). The overall mean RPE value was 15.7 (~16) which corresponds to a rating between “hard” and “very hard”. The overall median and mode values were both 17, which corresponds to a rating of “very hard”.

4.5 Sweat & Temperature Measures

No participants lost more than 2% body mass during any of the trials, and there were no observed significant differences in sweat rate (SW) among the treatments. There was no statistical significance amongst individual body temperature measurements (IBT/FBT) or environmental temperature measurements (dry & wet) (Table 4).

Table 4. Secondary Measures (Mean±SD)

	SW (L)	DTMP (°C)	WTMP (°C)	RPE (#)	IBT (°C)	FBT (°C)
W	0.94±0.22	26±0.3	19±0.1	15.5±2.07	36.5±0.5	37.5±0.5
G	0.94±0.22	26±0.3	19±0.2	16.1±1.72	36.8±0.4	37.8±0.5
CW	0.94±0.23	26.3±0.2	19±0.3	15.5±1.64	36.6±0.5	37.7±0.5

W=water, G=Gatorade[®], CW=coconut water, SW=sweat rate, DTMP=dry environment temperature, WTMP=wet environment temperature, RPE=rating of perceived exertion, IBT=initial body temperature, FBT=final body temperature; * $P<0.05$

5.0 Discussion

5.1 Coconut Water & Exercise Performance History

To our knowledge the literature contains only two studies, concerning the efficacy of CW as a hydration strategy for exercise performance. Both of these studies ultimately found that performance was not significantly different when hydrating with CW. Moreover, both studies have major design concerns. One study attempted to compare the efficacy of hydrating with CW versus a carbohydrate-electrolyte sports drink on endurance exercise performance. In that study a standardized breakfast consisting of “a bagel and one tablespoon of cream cheese” was used (Kalman et al., 2012) but there was no mention of other dietary control. Consequently, fuel availability could have differed across participants and/or treatments. When seeking to establish constant nutrition parameters, a controlled preparatory meal or two (relative to body mass) is needed to control both CHO and energy. Also, total exercise time to exhaustion was used as the performance measure (Kalman et al., 2012). This is problematic because any performance test relying upon the participant’s ability to perform until exercise exhaustion is neither reliable or applicable to most sporting performance. This is because most athletic contests do not involve designating the last man standing as the winner. Rather, the first contestant to cross the finish line is the winner, i.e., going faster for a given distance, not longer is what is important. Moreover, time to exhaustion exercise bouts typically depend more upon psychological motivation than underlying physiology/biochemistry. This likely explains why time to exhaustion tests have been known to have very poor reproducibility (Multer, 1993).

The second study that attempted to compare CW vs W as hydration strategies also involved endurance exercise performance, i.e., a 10 km time trial. The researchers’ decision to incorporate a time trial rather than a time to exhaustion test is an improvement compared to the Kalman et al. study (2012). Further, the investigators completed testing at the same time of day for each participant to control for circadian variations, they attempted to control diet [participants consumed a similar diet in the 24-hr period before each treatment (Peart et al., 2017)] but competed after a 4h fast which is not realistic for most athletes. Moreover, drink volume was not controlled and participants drank significantly less CW than W (~93 mL difference, $P < 0.001$) (Peart et al., 2016) which could affect performance. Finally, both of these studies examining

CW as a potential hydration beverage used prolonged endurance exercise so the results may not apply to other exercise types. Consequently, to our knowledge there are currently no studies that have examined the effects of hydrating with CW for sports involving intense, intermittent exercise, like basketball.

5.2 Hydration Effects on Basketball Skill Performance

In the present study, all the observed basketball skill performance indicators comparing hydration with G, CW, and W were non-significantly different except one. FGA was greater ($P=0.006$) in the 2nd quarter of the BSST when participants hydrated with CW vs both W and G. Specifically, FGA in the 2nd quarter were on average 5 attempts greater with CW vs G and 4 attempts greater vs W. Potentially, this could result in more field goals made and, in fact, FGM with CW was greater by 3 and 1 vs G and W, respectively but these observed differences did not reach statistical significance. Interestingly, although nonsignificant, FGM were also greater with CW in Quarter 1 vs G and W, by 9 and 5 baskets, respectively. Of course, with more FGA with CW the participants had a higher ceiling for shot attempts. Should they refine their shooting accuracy, perhaps these attempts could eventually result in more FGM. Should this occur, the result would be an increase of 8-10 points in a game. Perhaps with additional participants, or if the BSST had continued for a 3rd and 4th quarter, the observed greater FGA would have produced significantly greater FGM. These observations favouring CW are intriguing, especially because with 6 participants a Type II error is possible, but they are certainly far from conclusive. There was no indication that G was better than CW or W suggesting that for this basketball simulation pre-game body CHO stores were sufficient.

5.3 Hydration Effects on Basketball Fitness Performance

There were no significant differences for any fitness performance measures from the BEST suggesting all drinks studied were similar. Two of the observed findings did approach significance ($p<0.15$). First, MC in the 3rd quarter was slower with the G condition, but this observation is likely not real as it was even less apparent in quarter 4. Second, CD was worse with W in the 3rd quarter but again CD in the 4th quarter was similar with all 3 treatments so this

near significant finding is likely unimportant, as well. MS times for both the 3rd and 4th quarters were remarkably similar among drink treatments and TD was exactly the same so again there was little evidence that any drink studied was superior to the others.

5.4 Basketball Exercise Simulation Test

The Yo-Yo intermittent recovery tests (Bangsbo et al., 2008) have been some of the most extensively studied fitness tests in sports science and practice. The tests have been widely applied in many team sports to assess players' abilities to repeatedly perform intermittent high-intensity exercise (Bangsbo et al., 2008). Moreover, they have been relied upon for many years to reflect exercise intensities such as those found in team sports. The common pattern of play in team sports is "stop and go", where players perform repeated bouts of brief, high intensity exercise followed by low intensity physical activities (Williams & Rollo, 2015). However, the exercise activity components of the Yo-Yo tests are not specific to different team sports and do not incorporate sport-specific exercise activities that are found in different sports. For example, basketball-specific activities like defensive shuffling and jumping in the air increase the metabolic demands required of players during competition (Abdelkrim et al., 2007; McInnes et al., 1995). Furthermore, directional changes that occur in basketball competition also increase the metabolic demand of the players (McInnes et al., 1995). All of the previously existing acceptable basketball-specific fitness tests involve purely straight-line running or sprinting with no shuffling/jumping/directional changes. For these reasons, a group of researchers in 2012 attempted to create a basketball-specific exercise simulation test or "BEST" that overcomes the limitations listed above in the Yo-Yo intermittent recovery tests (Scanlan et al., 2012). To this date, there had been no developed protocols specific to basketball competition. Importantly, Scanlon and colleagues (2012) found that there was a strong relationship between the changes in BEST sprint decrement and changes in Yo-Yo intermittent recovery test performance ($R=-0.815$, $p=0.014$). Ultimately, they concluded that the BEST provided a novel match-specific fitness test for basketball players (Scanlan et al., 2012). The BEST represents basketball-specific fitness comprised of basketball-specific movements and correlated distances that are performed in one quarter of a basketball game. Two years later in 2014, this same group further substantiated their earlier findings and stated that: "the BEST is a reliable and valid match-specific test for the

combined assessment of basketball-related anaerobic and aerobic fitness” (Scanlan et al., 2014). Therefore, the BEST appears to represent a novel and sport-specific fitness test for basketball players. The applications of the BEST carry throughout training, player assessment, conditioning and research.

5.5 History of Measuring Basketball Performance

Despite the BEST being a “reliable and valid match-specific test for the combined assessment of basketball-related anaerobic and aerobic fitness” (Scanlan et al., 2014), sport specific skills are also a key part of assessing sport performance. Basketball-specific skill testing is not a component of the BEST. Basketball is not merely entirely running, shuffling, jogging, or jumping for 40 minutes. Basketball games cannot be won unless a team exhibits skills that result in baskets. Clearly, the technical aspects (sport skills) become extremely important for performance because the main objective of sports games is to score more goals/points than the opposition (Russell and Kingsley, 2014) but fitness is also important. All drills involved in the BSST were time trial based and included all locations on the basketball court (three-point, mid-range, free throw). Drills that only involve a few locations of the basketball court are not realistic as many players have “sweet spots” and, of course, players are expected to be able to shoot from many spots on the court. Four of the five drills used in the BSST assess a basketball player’s shooting ability from either the three-point line, the mid-range area, or the free-throw line or some combination of these locations. The jump-shot is a fundamental skill in basketball (Padulo et al., 2018) as is the three-point shot (Ardigò et al., 2018). All of the shooting drills in the BSST were dynamic in nature vs static, i.e., requiring the student-athletes to sprint from one spot to another on the court as fast as possible to maximize performance. Each participant was required to give a maximal effort during each section of the BSST. Emphasis was placed upon shooting drills because a basketball game cannot be won with passing/dribbling skills alone. The basketball has to pass through the net. Some studies in the past have used the “grab a ball from a cart” method but this is not realistic to basketball competition. There are no carts on the court with ~10 balls each waiting for players to grab and shoot from. Rather, the BSST incorporated a “catch and shoot” technique which is more realistic. Players must run to a designated spot on the court, catch a pass from a teammate and shoot the ball. Layup skill testing drills were not used -

as this skill, with a varsity basketball athlete by themselves on the court, would be futile. Further, dunking drills were not used as not all varsity basketball athletes can dunk. Only one drill assessed the basketball player's ability to dribble because although the dribbling skill is important, points are not awarded directly for skilled dribbling. Passing skill was not included.

Several previous studies have attempted to assess basketball skill performance through a variety of measures, including anthropometric measures (hand size & wingspan) (Haywood, 1978; Bale, 1991), anaerobic power (Wingate) tests (Scanlan et al., 2011), agility tests, change of direction tests, sprint tests, vertical jump tests (Ziv & Lidor, 2010), and grip strength tests (Bale, 1991) but were not used in this study because they are not specific to basketball competition (Carvalho et al., 2011). One study (Leite et al., 2014) even utilized an actual full game but this seems impractical as an entire game would be easy to repeat but not to reproduce with a similar outcome.

5.6 Menstrual Cycle and Oral Contraceptive Effects During Exercise

Female athletes are significantly under-represented in sport and exercise science research likely in part because the biphasic responses of oestrogen and progesterone across the menstrual cycle can influence physiological responses, which could affect performance (Sims & Heather, 2018). However, this hormonal response may not be attributable to all types, intensities, and durations of exercise. For example, hormonal contraceptive use by female athletes did not influence strength, endurance or body composition compared to female athletes who were not taking a hormonal contraceptive (Myllyaho et al., 2018). Moreover, although there was a reduction in maximal endurance performance during the mid-luteal phase of the menstrual cycle, this same effect was not observed for jumping and sprint performance (Julian et al., 2017). In addition, under hot and humid conditions, prolonged exercise performance, i.e. time to exhaustion, was reduced significantly in the luteal phase (Janse et al., 2012). However, for team sports or intermittent high intensity exercise, the effect of menstrual cycle phase and/or whether participants are taking an oral contraceptive do not have a significant effect on exercise performance (Rechichi & Dawson, 2009). This phenomenon has been also observed in

swimmers (Rechichi & Dawson, 2012), rowers (Vaiksaar et al., 2011), sprinters (Tsampoukos et al., 2010), cyclists (Kishali et al., 2006) and even strength athletes (Bushman et al., 2006). Consequently, Multer (1993) concluded that “regularly menstruating female athletes, competing in strength-specific sports and intense anaerobic/aerobic sports, do not need to adjust for menstrual cycle phase to maximise performance”. Based on this research, we did not feel that control of menstrual cycle or use of oral contraceptive was necessary in this study.

5.7 Limitations

There were a few limitations with the present study that need to be considered for future projects. Initially, an effort was made to have a double-blinded study, meaning both the participants and investigators would be unaware of what beverage was being ingested. Masking the taste differences without altering the beverage composition significantly proved too much of a challenge. Also, having a larger sample size is recommended going forward as it would minimize potential type II errors. Finally, completing the BEST first and BSST second might be able to tease out any drink differences on shooting performance if they exist as fatigue would be a greater factor.

5.8 Future Directions

This study is the first to examine G vs CW vs W with intermittent high intensity exercise, such as that found in team sports – specifically basketball performance. Most SDR today contain 6 – 8 g of CHO per 100 mL, yet not all team sports require this dosage. Also, not all SDR need to contain so much Na⁺. The ideal hydration beverage would be one that depends on the type, intensity and duration of the particular exercise the athlete is engaging in. Going forward, researchers should investigate each type of sport individually and attempt to fine-tune a hydration beverage that matches each sport. This concept is similar to that of appropriate footwear that is recommended for each unique sport/activity. Currently, all athletes are using the

same type of “footwear” in terms of a hydration beverage. So, there is certainly room for improvement.

5.9 Summary and Conclusion

Six varsity basketball athletes (n=6) each completed three - 40-minute, simulated basketball games which assessed basketball-specific fitness and basketball-specific skills while hydrating with CW, W, and G. FGA in the 2nd quarter of the basketball competition was greater (P=0.006) when hydrating with CW over W or G but all other measures of basketball performance/fitness were similar suggesting that there is no advantage of any drink over the others. Therefore, the original hypothesis must be rejected. More study with other high intensity intermittent exercise, and larger sample sizes are needed before any definitive recommendations can be made.

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Appendices

Appendix A. Human Ethics Approval



Date: 12 July 2018

To: Dr. Peter Lemon

Project ID: 111166

Study Title: The effect of coconut water on varsity basketball performance

Application Type: HSREB Initial Application

Review Type: Full Board

Meeting Date : 15/May/2018

Date Approval Issued: 12/Jul/2018

REB Approval Expiry Date: 12/Jul/2019

Dear Dr. Peter Lemon

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
DCF	Other Data Collection Instruments	Received June 29, 2018	
DCF3	Other Data Collection Instruments	Received June 29, 2018	
Reed Zehr LOI Consent June 25	Written Consent/Assent	25/Jun/2018	2
RZ Research Plan	Protocol	25/Jun/2018	2

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B. Letter of Information and Informed Consent



Title of Study:

The Effect of Coconut Water on Varsity Basketball Performance.

Principal Investigator:

Peter W.R. Lemon (PhD)
Graduate Student: Reed Zehr (B.Sc. (Hons))
Exercise Nutrition Research Laboratory
School of Kinesiology, Western University.

LETTER OF INFORMATION AND CONSENT

Invitation to Participate:

You are being invited to participate in a graduate student's research study at the Exercise Nutrition Research Laboratory. We will be investigating the effects of coconut water on basketball skills and physical performance during a simulated basketball game. You are being invited to the study because, as a varsity basketball player, you are recognized as an experienced, talented, and skilled athlete proficient in basketball related activities.

Purpose of the Letter:

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research.

Purpose of the Study:

The purpose of this study is to determine if there is a performance improving effect of hydrating with coconut water compared to other popular approaches (water and Gatorade®) for varsity basketball players during a simulated basketball game.

Inclusion Criteria:

In order to be eligible to participate in this study you must be a healthy male or female, aged 18-35 years old. You must also be a varsity basketball player.

Exclusion Criteria:

You will be excluded from this study if you:

- Are not a varsity basketball player
- Are not between the ages of 18-35 years old

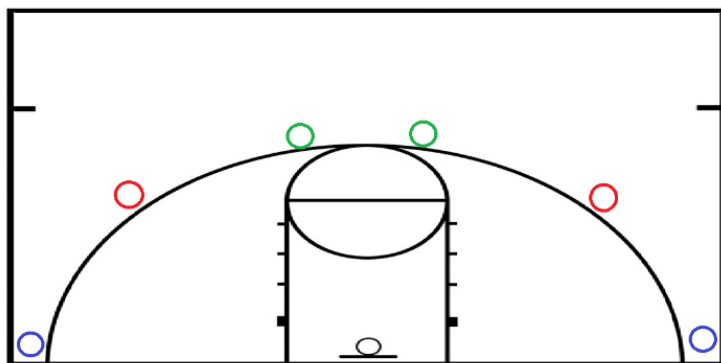
Study Outline:

This is a single blind study (meaning participants will know which drink is which but the investigators will not know which drink is which until the study is completed). A kinesiology student, Hannah Boettinger, will prepare all the drinks the night before. There will be three conditions studied (water, Gatorade[®], and coconut water) with a total of 30 participants (15 male and 15 female). The study incorporates a within individual design (each participant is his/her own control) completed on separate days with a minimum of a one week recovery period between each of the three sessions. All sessions will take place in the gym at Thames or Alumni Hall.

For each of the three experimental conditions (water, Gatorade[®], coconut water) you will compete the following basketball drills, designed to simulate the activities and effort involved in a basketball game.

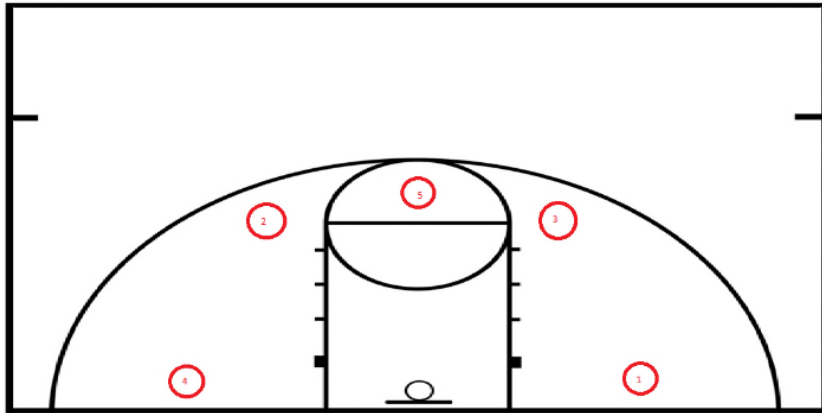
The Basketball Specific Skills Test (BSST): This test has 5 components beginning with a three point drill (you may know this drill as the “Ray Allen” drill – Figure 1). You start beside one of the green cones and attempt to make 3 point baskets. Alternating between only the green cones, shots will be attempted until 4 total baskets are made. The drill then continues using the same procedure at the red and then the blue cones. If you complete the entire circuit with time remaining you start again at one of the green cones. The drill continues for 2 minutes and is scored as the number of baskets made. All shots must be attempted from outside the 3 point arc or they do not count.

Figure 1



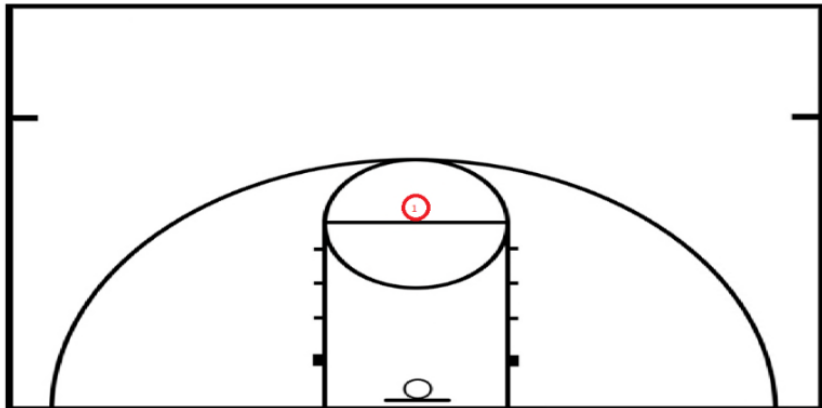
Next, you move as quickly as possible to cone 1 and continue with the “5-Star” drill (Figure 2). This drill involves shooting mid-range shots moving in sequential order from locations indicated by the 5 cones inside the 3 point line (Figure 2). This drill continues for 2 minutes and is scored as the number of baskets made.

Figure 2



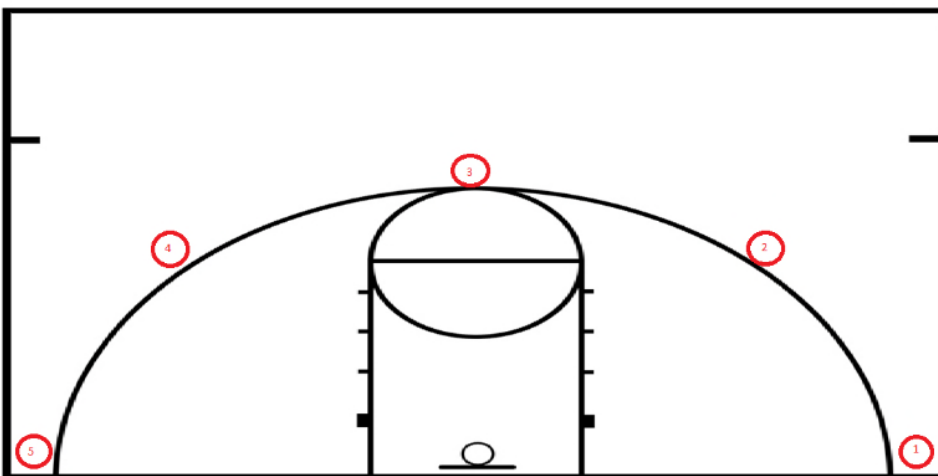
Then you will complete a free throw or “Steve Nash” drill (Figure 3). From the free-throw line you will attempt as many free-throws as possible in one minute. The drill is scored as the number of baskets made.

Figure 3



You will then complete the “5-step combo” drill which is a combination of three point shooting and mid-range shooting from each of the 5 cones (Figure 4). From each cone you will shoot 2 three point shots first, then take one dribble forward using your right hand into the mid-range area and shoot. Next you will take one dribble to your left with your left hand and shoot. Then you return to the same 3 point cone and shoot (for a total of 5 shots per cone). Next you progress as quickly as possible to the other cones in sequence and repeat the same 5 shots. The drill is scored as the number of baskets made in two minutes.

Figure 4



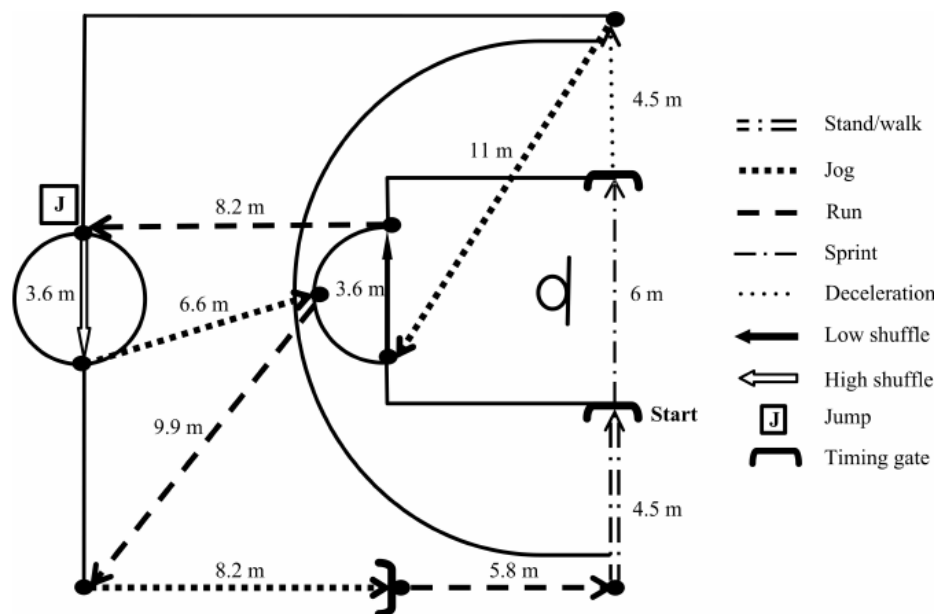
You will then dribble for 2 minutes in a stationary position performing a prescribed series of dribbles using your dominant hand. This drill involves 25 knee high dribbles, 25 ground tap dribbles, 25 pound and crossover dribbles, 25 pound and between legs dribbles, and 25 pound and behind back dribbles. Should you complete all the dribbles within 2 minutes, participants are instructed to start from the beginning again. This drill is scored as the number of dribbles completed.

Finally, you repeat the free throw drill (above – Figure 3) for 1 minute.

This test requires a total of 10 minutes. Field Goals Attempted (FGA) (#), Field Goals Made (FGM) (#), Field Goal Percentage (FGP) (%) will be measured during each of the shooting drills. Dribbles Performed (DP) (#) will be measured during the dribbling drill. **

The Basketball Exercise Simulation Test (BEST) includes several activities over a 10 minute time period (distance covered is about 1,438 metres). Each activity (Walking, Jogging, Running, Sprinting, Low shuffling, i.e., activity characterized by shuffling action of the feet within a defensive stance position at moderate pace, High shuffling, i.e., activity characterized by shuffling action of the feet within a defensive stance position, performed at maximal effort, and Jumping) is undertaken for 30 seconds. These activities are performed continuously for 10 minutes on a basketball court to simulate a quarter of basketball competition (Figure 5).

Figure 5



****Total distance covered (m), mean circuit completion time (s), mean sprint time (s), and total sprint decrement (%) will be measured during the BEST. ****

For the test days, you will arrive at the designated gym at 6:00am following an overnight fast (no food or drink after 7:00pm). Please refrain from strenuous exercise following the evening meal on the day before the test. The evening before the sessions, in the Exercise Nutrition Laboratory, you will be given a standard carbohydrate pasta meal of 3g CHO/kg body mass to ensure you will have the same energy for all testing days. The meal will be prepared by Reed Zehr. (Any conflicting food allergies/intolerances associated with any of the food will be addressed accordingly.) The morning of the exercise bout, having fasted from food and drink since dinner the preceding day, you will consume a standardized breakfast of toast and butter to replenish liver glycogen utilized overnight. This meal will be provided to you in the Exercise Nutrition Laboratory and prepared by Reed Zehr prior to arriving. This is to ensure you have adequate fuel reserves for the drills.

Study Procedures:

6:00am, arrive at Exercise Nutrition Laboratory

6:05am, change into appropriate sportswear

6:15am, consume first beverage (750mL) and standardized breakfast

6:30am, walk to Thames Hall Gym, warm up, stretch, review drill procedures and protocols

7:30am, consume second beverage (250mL)

7:45am, begin BSST #1

7:55am, begin first intermission of 2 minutes and consume third beverage (250mL)

7:57am, begin BSST #2

8:07am, begin halftime period of 15 minutes and consume fourth beverage (500mL)

8:22am, begin BEST #1

8:32am, begin second intermission of 2 minutes and consume fifth and final beverage (250mL)
8:34am, begin BEST #2
8:44am, end of session

****Repeat procedure with the other two drinks following a week of rest/recovery****
****Total time: 2.75h****

Possible Risks and Harms:

The basketball drills require strenuous exercise that could result in minor muscle injury as well as discomfort, soreness, and/or fatigue. All of these are transient and of little concern. Of course, there is some health risk (primarily cardiovascular or hydration-related) with any exercise but these risks are very low, especially in young, physically active individuals. Further, you complete similar exercise daily in practice and we are providing fluid replacement drinks during the study so participation in this study involves very low risk of any of these concerns and, importantly, no greater risk than you experience regularly in your workouts.

Potential Benefits:

There is no direct benefit to you from participating in this particular study. You may gain knowledge of some strategies to maximize performance through nutritional interventions. You will also receive the experimental results (mean \pm SD) once everything is completed, if you request them.

Compensation:

You will not be compensated for your participation in this study nor will you be reimbursed for any additional costs incurred such as parking or transportation.

Voluntary Participation:

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time without a penalty of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so. Participation in this study will in no way affect your academic standing or your position on the Varsity Basketball Team.

Rights of a Participant (in the event of a study related injury):

If you suffer any study related injury during your participation in this study care will be provided to you at no cost.

Confidentiality:

If you agree to join this study, only members of the study team will look at your personal information (e.g., name, experimental results, etc.) and only the information they need for the study will be collected.

Further, all information that is collected for the study will be coded so you cannot be identified. The master list kept in a secure area (on a University server behind a fire wall) by the study doctor for 7 years. Only the study team or the people or groups listed below will be allowed to look at your records. Identifiable data will only be kept for 7 years, whereas de-identified data

will be kept indefinitely on a kinesiology server. These data will be in numerical form only. No personal identifiers will be present. These data may be compared to the results of future similar studies.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board may look at the study records and at your personal health information to check that the information collected for the study is correct and to make sure the study followed proper laws and guidelines.

All information collected during this study will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

If you decide to leave the study, the information about you that was collected before you leave the study will still be used in order to answer the research question. No new information will be collected without your permission.

Contact for Further Information:

If you have any questions about this research project, feel free to call us for clarification. Further, if you have any questions about the conduct of this study or your rights as a research participant you may contact the Office of Research Ethics at Western University.

Publication

If the results of the study are published, your name will not be used. If you would like to receive a copy of any potential study results, please contact Reed Zehr.



Consent Form

The Effect of Coconut Water on Varsity Basketball Performance.

Investigators: Peter W.R. Lemon, (PhD) and Reed Zehr, (B.Sc. (Hons))

I have read the accompanying "Letter of Information", have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

If you wish to participate in future studies in the Exercise Nutrition Research Lab, the research team will collect your contact information.

I wish to be contacted for future studies in the Exercise Nutrition Research Laboratory.

Yes _____ (check mark) No _____ (check mark) Date: _____

By signing below, I agree to participate in this study.

Name of Participant (please print): _____

Signature of Participant: _____ Date: _____

Name of Person Obtaining Informed Consent: _____

Signature of Person Obtaining Informed Consent: _____

Date: _____

You will receive a copy of the consent form after it has been signed. You do not waive any legal rights by signing the consent form.

This letter is for you to keep for future reference.

Sincerely,

Dr. Peter Lemon
Principal Investigator

Reed Zehr, B.Sc. (Hons)

Appendix C. Ratings of Perceived Exertion (RPE) Scale**Borg Scale (6-20)**

Rating	How Hard you are Exercising
6	No, exertion at all
7	Very, very light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal Exertion

Appendix D. Nutritional Food Labels of Products Used

1. Gatorade®:

Nutrition Facts	
Serving Size 12 fl oz (355 mL)	
Servings Per Container about 2.5	
Amount Per Serving	
Calories 80	
	% Daily Value*
Total Fat 0g	0%
Sodium 160mg	7%
Potassium 45mg	1%
Total Carbohydrate 22g	7%
Sugars 21g	
Protein 0g	
Not a significant source of calories from fat, saturated fat, trans fat, cholesterol, dietary fiber, vitamin A, vitamin C, calcium and iron.	
* Percent Daily Values are based on a 2,000 calorie diet.	

2. Thai Heritage Coconut Water®:

Nutrition Facts	
Valeur nutritive	
Per 1/2 Can (260 mL)	
Pour 1/2 canette (260 mL)	
Amount	% Daily Value
Teneur	% valeur quotidienne
Calories / Calories 60	
Fat / Lipides 0 g	0 %
Saturated / saturés 0 g + Trans / trans 0 g	0 %
Cholesterol / Cholestérol 0 mg	
Sodium / Sodium 80 mg	3 %
Potassium / Potassium 560 mg	16 %
Carbohydrate / Glucides 15 g	5 %
Fibre / Fibres 0 g	0 %
Sugars / Sucres 11 g	
Protein / Protéines 0 g	
Vitamin A / Vitamine A	0 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	4 %
Iron / Fer	0 %
INGREDIENTS: COCONUT WATER 100%	

Curriculum Vitae

Name: Reed Zehr

Post-secondary Education and Degrees: University of Waterloo
Waterloo, Ontario, Canada
2009-2016, B.Sc. (Hons)

University of Western Ontario
London, Ontario, Canada
2017-2019, M.Sc.

Honours and Awards: Applied Health Sciences Entrance Scholarship,
2009

Western Graduate Research Scholarship,
2017-2018, 2018-2019

Related Work Experience: Teaching Assistant
University of Western Ontario
2017-2019