Physiological adaptations to training and associations with performance in Division I cross-country runners

Kailyn Renae Sanchez

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PHYSIOLOGICAL ADAPTATIONS TO TRAINING AND ASSOCIATIONS WITH PERFORMANCE IN DIVISION 1 CROSS-COUNTRY ATHLETES

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Chapter 1

Introduction

The sport of cross-country is a long-distance running event that takes place over outdoor courses (Kostek & Seewald, 2018). In 1898, the first international cross-country race was held in France (International Association of Athletics Federation, 1996). Shortly thereafter, the International Association of Athletics Federation (IAAF), the world governing body for track and field athletics, established official sport guidelines (International Association of Athletics Federation, 1996). The first official National Collegiate Athletics Association (NCAA) Division-1 men’s cross-country race was held in 1938, while the first women’s cross-country race took place in 1981 (NCAA, 2019).

According to NCAA guidelines, courses must be a minimum of 4,000 meters for men and 3,000 meters for women (Kostek & Seewald, 2018). The championship race must be between 8,000 to 10,000 meters and 5,000 to 6,000 meters for men and women, respectively (Kostek & Seewald, 2018). Although it is an individual sport, cross-country is also based on team performance (Kostek & Seewald, 2018). Each team member receives a score dependent on their race placement; these scores are totaled, and the final score reflects the team’s standing in the competition (Kostek & Seewald, 2018). The sport has continued to gain popularity, with approximately 30,000 individuals competing worldwide within the past year (Johnson & Schwarb, 2018). In 2017-18, 96.1% of NCAA schools sponsored the sport, with 15,632 NCAA athletes competing (Johnson & Schwarb, 2018).
Successful distance running is influenced by factors which include, maximal aerobic capacity (Jones & Carter, 2000), anaerobic threshold (Caiozzo et al., 1982), dietary intake (Thomas, Erdman, Burke, & MacKillop, 2016), and body composition (Thomas et al., 2016). Maximal aerobic capacity ($\text{VO}_2\text{max}$) is defined as the maximal rate at which oxygen can be taken up and used by the body (Hill & Lupton, 1923). This parameter is a key determinant of endurance performance and can be assessed through measurement of $\text{VO}_2\text{max}$ (Costill, Thomason, & Robert, 1973). Improvements in maximal aerobic capacity ($\text{VO}_2\text{max}$) are dependent on factors including training intensity (Milanovic, Sporis, & Weston, 2015) and genetic factors (Bouchard et al., 1999).

Anaerobic threshold is also a predictor of endurance performance in long distance runners (Yoshida, Chida, Ichioka, & Suda, 1987) and can be described by both lactate threshold and ventilatory threshold (Caiozzo et al., 1982; Farrell, Wilmore, Coyle, Billings, & Costill, 1979). Lactate threshold, the exercise intensity at which blood lactate accumulation exceeds lactate clearance, is commonly expressed as the $\text{VO}_2\text{max}$ percentage at which athletes achieve this state (Farrell et al., 1979). Ventilatory threshold, the intensity at which ventilation increases disproportionate to oxygen consumption is also expressed in relation to $\text{VO}_2\text{max}$ percentage (Caiozzo et al., 1982).

Previous literature has assessed longitudinal adaptations in maximal aerobic capacity ($\text{VO}_2\text{max}$) and anaerobic capacity in cross-country runners. Research is conflicted on the precise changes in these parameters that occur over a season of competition, with some studies indicating improvements (Acevedo & Goldfarb, 1989; Galbraith, Hopker, Cardinale, Cunniffe, & Passfield, 2014; Svedenhag & Sjodin, 1985) and others reporting no significant changes (Baumann & Wetter, 2010). Additional research indicates that
racing performance may also improve over a season (Acevedo & Goldfarb, 1989; Berg, Latin, & Hendricks, 1995; Plank et al., 2005) and these improvements may be related to changes in maximal aerobic and anaerobic capacity (Plank et al., 2005).

Total energy (kcal) intake also plays a role in endurance athlete performance (Burke, Millet, & Tarnopolsky, 2007; Thomas et al., 2016). Athletes must meet higher caloric requirements than the general population because of the increased energy (kcal) expenditure associated with participation in sport (Thomas et al., 2016). Despite increased caloric requirements, athletes often do not consume sufficient calories to support performance (Hinton, Sanford, Davidson, Yakushko, & Beck, 2004; Nutter, 1991; Shriver, Betts, & Wollenberg, 2013; Tanaka, Tanaka, & Landis, 1995; Thomas et al., 2016). The energy (kcal) deficit incurred by exercise does not increase hunger, thus, athletes may be unaware of deficits in total kcal intake (Loucks, 2007). Previous studies have assessed the changes in energy (kcal) intake that take place over a season in endurance athletes. Research is conflicted, with some studies indicating that athletes demonstrate sufficient energy (kcal) intake (Niekamp & Barr, 1995) and others highlighting deficits in energy (kcal) intake (Nutter, 1991).

Inadequate caloric intake may lead to Relative Energy Deficiency in Sport (RED-S) (Mountjoy et al., 2014). This syndrome is caused by energy (kcal) deficiency and encompasses the system-wide harmful effects of severe caloric restriction in athletes (Mountjoy et al., 2014). Specifically, RED-S refers to the impaired physiological function of various body systems, including decreased or impaired metabolic rate, bone health, immunity, protein synthesis, cardiovascular health, and, in females, menstrual function (Mountjoy et al., 2014). Additional consequences include lack of energy for
competition, inability to replace glycogen stores, lack of protein for tissue building and repair, and micronutrient deficiency. These deficits lead to impaired metabolism and body homeostasis (Beals & Manore, 1994). Unintentional and intentional restricted calorie consumption may also suppress bone formation leading to osteoporosis (Loucks, 2007). Additionally, RED-S includes psychological disturbances associated with caloric restriction such as depression and clinical eating disorders, like anorexia nervosa and bulimia nervosa (Mountjoy et al., 2014).

Additionally, body composition (fat mass and fat-free mass) influences endurance athlete performance (Loucks, 2007; Thomas et al., 2016). Distance runners are typically characterized by lower levels of body fat and higher levels of lean mass, which allow for more economical running behavior (Burke et al., 2007) and improved thermoregulatory capacity (O'Connor & Slater, 2011). Runners, however, may strive to alter body composition through extreme caloric restriction or excessive exercise because of the perception that this will enhance performance (Benson, Gillien, Bourdet, & Loosli, 1985; Burke et al., 2007; Loucks, 2007; Thomas et al., 2016). Some previous research demonstrates non-significant changes in body composition (fat mass and fat-free mass) in cross-country athletes over a season of competition (Baumann & Wetter, 2010; Niekamp & Barr, 1995). Fat-free mass may increase in response to a season of training and this increase may be associated with improved performance (Berg et al., 1995; Legaz & Eston, 2005).

Ultimately, optimal energy (kcal) intake and body composition (fat mass and fat-free mass) can play a role in enhancing performance; however, previous research (Benson et al., 1985; Burke et al., 2007; Loucks, 2007) suggests that these issues should
be examined from a preventative standpoint in athletes. Specifically, athletes often engage in excessive exercise or may restrict caloric intake to alter body composition (Beals & Manore, 1994). If unaddressed, these behaviors may severely impair performance (Burke et al., 2007).

In addition, participation in sport is highly demanding and may negatively impact the academic performance (Cosh & Tully, 2012), sleep behavior, body image, and overall stress (Selby, Weinstein, & Stewart, 1990) of the student-athlete. Cosh and Tully (2015) stated that student-athletes should develop effective strategies for withstanding the demands associated with this role. Adequate social support has been shown to be an important resource for the student-athlete as they cope with the demands of sport participation (Cosh & Tully, 2015). This construct has been shown to positively influence stress-management (Cosh & Tully, 2015), athletic performance (Freeman & Rees, 2008), and recovery from injury (Yang, Peek-Asa, Lowe, Heiden, & Foster, 2010). Social support is defined as the social resources perceived by or provided to the individual by their support group (Cohen, Underwood, & Gottlieb, 2000). Adequate social support has been shown to have positive effects on physiological processes, specifically relating to the cardiovascular, endocrine, and immune systems (Uchino, Cacioppo, & Kiecolt-Glaser, 1996). This resource also plays a role in overall physical (Berkman & Syme, 1979) and mental health (Aneshensel & Frerichs, 1982). Although previous studies have identified the importance of social support in student-athletes (Cosh & Tully, 2015; Freeman & Rees, 2008; Yang et al., 2010), little research has examined how this construct changes over a season in this population.
Problem Statement

Cross-country athlete performance is influenced by multiple factors; however, previous research is conflicted over the specific changes in maximal aerobic capacity (VO\textsubscript{2max}) and ventilatory threshold that occur over a season and how these changes influence performance. Additionally, little research has examined changes in body composition, dietary adequacy, and perceived social support over a competitive season in cross-country athletes, as well as how these changes relate to performance. Therefore, the purpose of this study is to observe changes in maximal aerobic capacity, ventilatory threshold, dietary intake, body composition, and perceived social support over a cross-country season in collegiate student-athletes, as well as the relationships of these variables on race performance.

Null Hypotheses

H\textsubscript{01}: There will be no significant changes in relative peak aerobic capacity (VO\textsubscript{2peak}), ventilatory threshold, daily caloric intake (total kcal), body composition (fat mass and fat-free mass), or perceived social support of NCAA D-1 male and female cross-country athletes across a competitive season.

H\textsubscript{02}: There will be no significant association between peak aerobic capacity (VO\textsubscript{2peak}), ventilatory threshold, fat-free mass, or perceived social support with race performance in NCAA D-1 male and female cross-country athletes across a competitive season.
H₀₃: There will be no significant prediction of race performance by peak aerobic capacity (VO₂peak), ventilatory threshold, fat-free mass, or perceived social support in NCAA D-1 cross-country athletes across a competitive season.

**Dependent Variables**

Dependent variables include relative VO₂peak, ventilatory threshold, total caloric intake, percent fat mass, kilograms of fat-free mass, and perceived social support score.

**Operational Definitions**

VO₂peak (ml·kg⁻¹·min⁻¹) was defined as the highest value recorded during the last minute of exercise (Astorino et al., 2000; Lamberts, 2014). Additional criteria were used to determine that maximal effort was achieved, including, a respiratory exchange ratio (RER) value ≥ 1.05-1.15, and/or a heart rate within 10-12 beats of maximal heart rate using the equation developed by Tanaka, Monahan, & Seals (2001) (208 – 0.7 x age) (Beam & Adams, 2001). Ventilatory threshold (%VO₂peak) was defined as the point at which the VCO₂ and VO₂ regression lines intersected, using the automated V-slope method (ParvoMedics TrueOne 2400, Salt Lake City, Utah).

Dietary intake was defined by the total number of calories that athletes self-reported in a 24-hour dietary recall. Perceived social support was defined as a participant’s score from the 16-item Perceived Available Support in Sport Questionnaire (PASS-Q). This questionnaire was designed by Freeman et al. (2011), with higher scores indicating higher levels of social support.

A competitive cross-country season was defined as lasting between June Ninth, following conclusion of the outdoor track season, and December 2019 after the last race of the season. Training load was defined by weekly running mileage and frequency of
training. Race performance was defined as average race time in the most frequently competed in race across the season. Race performance was defined using average eight-kilometer race time in males and average six-kilometer race time in females.

**Assumptions**

It is assumed that athletes followed pre-test instructions to the best of their ability. It is also assumed that athletes self-reported their dietary intake honestly and accurately when completing the 24-hour dietary recall. It is assumed that athletes self-reported weekly training load honestly and accurately. It is assumed that athletes will complete the VO_{2max} test with maximal effort, to best of their ability.

**Delimitations**

Participants were delimited to male and female cross-country athletes who are cleared for sport participation by Eastern Washington University.

**Limitations**

Dietary information was gathered through a self-reported 24-hour dietary recall which will limit both the quantity and quality of the information obtained. The first testing session occurred the week after the conclusion of the outdoor track season; thus, VO_{2max} may reflect cumulative fatigue from training and competition. Athletes began the season with various levels of fitness; thus, this may impact improvements observed over the competitive season. Athletes had different levels of experience racing in college which may impact and race performance. Physical activity was not controlled, therefore, varying levels of physical activity among athletes may have contributed to physiological changes observed. Athletes competed at cross-country courses which varied in length and
terrain over the season. Therefore, these differences may have caused some variance in the race times achieved.

**Significance**

Thus far, no research has examined changes in peak aerobic capacity (VO\textsubscript{2peak}), ventilatory threshold, body composition (fat mass and fat-free mass), dietary intake (total kcal), and social support concurrently over a season and how these variables are individually associated with race performance. The association of these variables with performance and athlete health (Cosh & Tully, 2015; Jones & Carter, 2000; Mountjoy et al., 2014; Thomas et al., 2016) indicate that this is an issue that should be studied further in this population. Thus, this longitudinal study design allowed assessment of changes in these parameters over a season, which may provide further insights related to performance potentiation, especially when considered concurrently with dietary intake, fat mass, fat free mass, and social support.
Chapter 2

Literature Review

Introduction

Successful distance running is influenced by various parameters which include, maximal aerobic capacity (VO$_{2\text{max}}$) (Jones & Carter, 2000), anaerobic threshold (Jones & Carter, 2000), body composition (fat mass and fat-free mass) (Thomas, Erdman, & Burke, 2016), and dietary intake (total kcal) (Thomas et al., 2016). Higher VO$_{2\text{max}}$ values are a predictor of endurance race performance (Jones & Carter, 2000); however, improvements in race performance have been seen in endurance athletes, independent of increases in VO$_{2\text{max}}$ (Lucia et al., 2006; Saltin et al., 1995). Additionally, the anaerobic threshold (lactate and ventilatory threshold) influences performance (Jones & Carter, 2000). For example, a high anaerobic threshold allows a runner to periodically sprint during a distance run. This ability may allow athletes to strategically break away from the pack or to sprint at the end of a race (Bulbulian, Wilcox, & Darabos, 1986). Lactate threshold has also been shown to be highly correlated with VO$_{2\text{max}}$ and endurance running performance (Yoshida et al., 1986). Additionally, body composition influences running performance, a low percentage of body fat and a high percentage of lean mass allowing for improved thermoregulatory capacity and movement efficiency (Berg, 2003; Loucks, 2007; Thomas et al., 2016). Sufficient energy (kcal) consumption provides endurance athletes with adequate energy for competition and is essential for proper recovery (Burke et al., 2007; Thomas et al., 2016). Along with the physiological and dietary parameters associated with athlete success, additional resources such as social
Previous research has been devoted to maximal aerobic capacity (VO\textsubscript{2max}), anaerobic threshold, body composition (fat mass and fat-free mass), dietary intake (total kcal), and social support in endurance athletes. Little research, however, has examined how these parameters may change over an entire season and to what extent those changes might affect race performance during that season. Therefore, the purpose of this review is to highlight previous research assessing changes in maximal aerobic capacity (VO\textsubscript{2max}), anaerobic threshold, body composition (fat mass and fat-free mass), dietary intake (total kcal), and social support in university cross-country athletes over the course of a competitive season, as well as potential relationships between these variables and race performance.

**Physiological Adaptations to Training and Associations with Race Performance**

Improvements in maximal aerobic capacity (VO\textsubscript{2max}) between 20-25% have been reported in untrained individuals engaged in ten weeks of consistent running (Hickson, 1980). Consistent training also induces physiological adaptations in trained runners (Svedenhag & Sjodin, 1985). However, adaptations may be lower in this population. Improvements between five and ten percent have been reported in trained participants over eight weeks of consistent running (Helgerud, Engen, Wisloff, & Hoff, 2001; Helgerud et al., 2006). Adaptations in VO\textsubscript{2max} are partially dependent on intensity of training (Milanovic, Sporis, & Weston, 2015) and genetic factors (Bouchard et al., 1999). In addition to training status, age plays a role in adaptations; thus, differences may be observed between adolescent, elite, and collegiate runners (Jones & Carter, 2000).
Ultimately, the various factors which influence race performance must be considered when reviewing previous literature.

Previous research is conflicted about the precise adaptations that occur in maximal aerobic capacity (VO$_{2\text{max}}$) and anaerobic threshold in endurance athletes in response to training. Sport-specific training may result in improvements in these parameters and subsequently potentiate performance (Arrese, Ostariz, Mallen, & Izquierdo, 2005; Baumann, Rupp, Ingalls, & Doyle, 2012; Plank, Hipp, & Mahon, 2005). Conflicting studies have indicated improvements in racing performance independent of VO$_{2\text{max}}$ increases (Berg, Latin, & Hendricks, 1995). Among other factors, these improvements in performance independent of VO$_{2\text{max}}$ may be due to adaptations in running efficiency, lower blood lactate levels during exercise, or the ability to run at a higher fraction of VO$_{2\text{max}}$ during a race (Lucia et al., 2006; Saltin et al., 1995).

This relationship has been observed in adolescent cross-country runners (Cunningham, 1989; Plank et al., 2005). In a cross-sectional study, Cunningham (1989) found that the adolescent female runners with faster racing times also had significantly higher VO$_{2\text{max}}$ values when compared with other similar athletes. VO$_{2\text{max}}$ and ventilatory threshold were compared between athletes ($n=20$) from four high school cross country teams. No significant differences in ventilatory threshold were found between teams; however, significant differences in VO$_{2\text{max}}$ were observed between teams. Specifically, the fastest team, Team 1, achieved a significantly higher average VO$_{2\text{max}}$ ($70 \pm 4$ ml/kg/min) than Team 3 ($56.5 \pm 4$ ml/kg/min) and Team 4 ($58.6 \pm 4$ ml/kg/min) ($p < 0.05$). Team 1 also demonstrated the fastest average 5-km race time (min) overall ($19:23 \pm .06$ vs. $20:23 \pm 1.01$ vs. $21.07 \pm 1.12$ vs. $21:17 \pm 1.11$) and placed first in the All-State
Meet. The differences in race times between teams were not statistically significant; however, the success of the team with the highest VO$_{2\text{max}}$ provides evidence that this variable is an indicator of performance in adolescent cross-country runners.

A longitudinal study by Plank et al. (2005) also supports the relationship between VO$_{2\text{max}}$ and performance in adolescent cross-country runners. After nine weeks of off-season training (41.2 ± 14.5 km/wk), VO$_{2\text{max}}$, submaximal blood lactate, and 5-km race performance were assessed in adolescent (n=9; 15.9 ± 1.0 yrs) male runners at the beginning and end of a thirteen-week season. VO$_{2\text{max}}$ was assessed through a graded treadmill test in which participants began running at 9.0 km/hr with a 0% grade for two minutes. Treadmill speed was then increased 1.0 km/hr every minute until 14.0 km/hr was reached. At this time, grade was progressively increased by 1.5% each minute until maximal voluntary effort. Blood lactate was measured with a separate protocol in which participants completed six-minute intervals of running at 10, 12, and 14 km/hr. Five-km race time (18:41 ± 1:06 to 18:10 ± 1:06), graded exercise test time, absolute VO$_{2\text{max}}$, and relative VO$_{2\text{max}}$ (61.6 ± 3.5 to 65.3 ± 2.9 ml/kg/min) improved significantly over the season (p<0.05). Five-km race time was significantly related to submaximal blood lactate (r = 0.77; p<0.05) and graded exercise test time (r = -0.69; p<0.05) but not VO$_{2\text{peak}}$ (r = -0.18). Despite this non-significant correlation between VO$_{2\text{peak}}$ and race performance, Plank et al. (2005) did observe significant improvements in VO$_{2\text{max}}$ and racing performance over the season. In association with the results of Cunningham (1989), this study suggests that VO$_{2\text{max}}$ does influence the racing performance of adolescent runners.

This relationship has also been demonstrated in trained adult runners. Arrese et al. (2005) found improvements in VO$_{2\text{max}}$ and racing performance in trained adult runners.
Male \((n=25; 23 \pm 4.2 \text{ yrs})\) and female \((n=8; 26.2 \pm 5.4 \text{ yrs})\) athletes were separated into \textit{Class A} or \textit{Class B} groups based on race time. Faster athletes were designated to the \textit{Class A} group and slower athletes to the \textit{Class B} group. In the more elite \textit{Class A} athletes, three years of training resulted in non-significant improvements in race performance and no significant increases in \(VO_{2\text{max}}\). In \textit{Class B} runners, race time significantly decreased by 3.16\% \((p = 0.001)\) and \(VO_{2\text{max}}\) increased by 0.69 \(\text{ml/kg/min}\) \((p = 0.557)\) over the study duration. Thus, improvements in \(VO_{2\text{max}}\) and racing time may be most clearly seen in less elite adult athletes. Furthermore, such adaptations may require a multi-year time frame to manifest.

Associations between \(VO_{2\text{max}}\) and race performance have also been identified in older trained endurance athletes (Saunders, Cox, Hopkins, & Pyne, 2010). \(VO_{2\text{max}}\), peak running speed, and lactate threshold were assessed over 17-weeks in male runners \((n=34; 32 \pm 7 \text{ yrs})\) training for competition in road and cross-country races (5-21 km). Participants completed an incremental treadmill test at four points throughout the study to assess \(VO_{2\text{max}}\). Participants began the test by running at 14 km/hr \((0\% \text{ gradient})\), with speed being increased by 1.0 km/hr each minute until they achieved 18 km/hr. Treadmill grade was then increased by 1\% every minute until volitional exhaustion. Surprisingly, changes in \(VO_{2\text{max}}\) were not reported at each time point; however, when all four tests were averaged, participants achieved an average \(VO_{2\text{max}}\) of 64 \(\text{ml/kg/min}\) across the 17-week study. \(VO_{2\text{max}}\) was found to be both significantly and highly correlated to peak running speed \((r = 0.86)\). Linear regression revealed that \(VO_{2\text{max}}\) had the strongest relationship with peak speed, and thus, was the greatest predictor of peak speed (Saunders et al., 2010). The peak speed of an athlete may influence their race
performance; thus, this study supports the work of Arrese et al. (2005), demonstrating the importance of these variables in highly trained older runners.

Improvements in these variables have also been observed in collegiate runners. Harber, Gallagher, Creer, Minchev, and Trappe (2005) assessed 8-km race times and relative VO$_{2\text{max}}$ (ml/kg/min) in a longitudinal study of NCAA D-1 male cross-country runners ($n=5$). VO$_{2\text{max}}$ was determined through an incremental treadmill protocol at three time points over the 12-week cross-country season. Athletes were tested at three time points during a cross-country season. Athletes initially averaged 99 km/wk during the season; however, run volume decreased and the proportion of interval runs increased as the season progressed. Although the improvements were not statistically significant, increases in VO$_{2\text{max}}$ were observed over the season, (70.5 ± 0.7 to 71.7 ± 1.2 ml/kg/min). Improvements in 8-km race time, which trended toward significance, were also observed at each time point. Specifically, race time (min) decreased by 2.8% between T1 and T2 (27.43 ± 0.31 vs. 26.65 ± 0.20; $p=0.053$) and by 1.1% between T2 and T3 (26.65 ± 0.20 to 26.36 ± 0.26). Despite non-significant results, improvements in both VO$_{2\text{max}}$ and racing time were seen in collegiate athletes, a finding which obviously has practical implications for the cross-country athlete.

Lambert and Costill (1996) observed increases in VO$_{2\text{peak}}$ and test time to exhaustion; however, unlike Harber et al. (2005), they did not gather data on race performance. Collegiate distance runners ($n=7$) averaging 83 km/wk were assessed at three time points across a 13-week season. VO$_{2\text{peak}}$ and test time to exhaustion were assessed with a standardized progressive protocol at three time points, pre-season, mid-season, and post-season. VO$_{2\text{peak}}$ was assessed through an incremental treadmill test in
which participants ran at 16.09 km/hr while grade was increased by 2% every two minutes until exhaustion. Time to exhaustion was recorded at the end of each test. VO$_{2\text{peak}}$ (68.9 ± 1.8 vs. 72.4 ml/kg/min) and time to exhaustion (7.6 ± .04 vs. 8.5 ± 0.3 min) increased significantly over the season (p<0.05). These results corroborate previous research (Arrese et al., 2005; Harber et al., 2005), demonstrating the adaptations that occur over a cross-country season in collegiate runners.

In addition, a cross-sectional study published by Baumann et al. (2012) further supports the potential relationship between VO$_{2\text{max}}$ and racing performance and highlights the influence of the anaerobic threshold on racing performance. In NCAA D-1 female cross-country runners (n=13), VO$_{2\text{max}}$ was assessed through an incremental treadmill test. Maximal anaerobic capacity was measured through an intermittent, high-intensity treadmill test. VO$_{2\text{max}}$ was significantly correlated with 5-km race time (r = .80, p < .01) and maximal anaerobic capacity (r = .69, p < .01). This study provides further evidence for the link between adaptations in VO$_{2\text{max}}$ and improvements in performance in collegiate cross-country runners.

In conclusion, previous research supports the relationship between VO$_{2\text{max}}$ and racing performance in trained adolescent, adult, and collegiate runners. The extent of this relationship may be dependent on factors such as age, training status, study time course, and training intensity and frequency. Adaptations may be most clearly seen in less trained runners or when runners engage in training of a higher volume or intensity; however, it is apparent that improvements in VO$_{2\text{max}}$ often support improvements in overall performance.
In contrast, previous literature also indicates that VO\textsubscript{2max} may improve without concurrent improvements in racing time. Svedenhag and Sjodin (1985) observed VO\textsubscript{2max} increases in elite, long-distance (n=5; 21.2 yrs) and middle-distance male runners (n=5; 22.6 yrs) over a year of training. Initially, long slow distance training was emphasized; however, as the season progressed, the weekly number of high-intensity workouts increased. VO\textsubscript{2max} was assessed at four time points, with participants running at a previously selected speed (16.0-17.5 km/hr) while treadmill grade was increased by 0.5% every 30 seconds for 4 minutes and by 0.5% every minute thereafter. Relative VO\textsubscript{2max} increased significantly (74.2 to 77.4 ml/kg/min) over six months, notably, in the transition from January to the competitive summer season (p < 0.01); however, no significant changes in race time were seen. The increase in relative VO\textsubscript{2max} may be attributable to the increased number of high-intensity workouts incorporated into training. Additionally, VO\textsubscript{2max} decreased significantly (77.4 ml/kg/min to 75.0 ml/kg/min) (p<0.01) after the competitive season, indicating that maintenance of VO\textsubscript{2max} is dependent on consistent training.

In a longitudinal study, Galbraith et al. (2014) also assessed training and resulting changes in male distance runners (n=14; 28 ± 8 yrs) over a year of training and competition. Athletes were tested during the pre-season (April), mid-season (October), and post-season (January). VO\textsubscript{2max} was assessed through a graded exercise test in which the treadmill incline was progressively increased each minute until volitional exhaustion. No significant changes in lactate threshold or running speed were observed over the year. Significant increases in absolute and relative VO\textsubscript{2max} (69.8 ± 6.3 to 74.0 ± 4.4 ml/kg/min) were seen during the mid-season assessment (p<0.01). Race times were not reported;
thus, these increases in \( VO_{2\text{max}} \) cannot be directly related to racing performance. The results of Galbraith et al. (2014) support the work of (Svedenhag & Sjodin, 1985), indicating that a year of training produces small but significant increases in \( VO_{2\text{max}} \) even if changes in racing performance do not occur.

It has also been shown that a training season may not elicit physiological adaptations in runners. Baumann and Wetter (2010) assessed relative \( VO_{2\text{max}} \), ventilatory threshold, onset of blood lactate accumulation, and anaerobic power in NCAA D-III male runners \((n=8)\) before and after an eight to ten-week cross-country season. Runners trained at a high-volume \((112.6 \pm 18.3 \text{ km/wk})\) in the month prior to the start of the season; however, during the season, volume was significantly decreased \((84.3 \pm 16.6 \text{ km/wk})\) \((p = 0.003)\), while intensity increased. Athletes also completed one or two weekly training sessions at a higher intensity than their racing speed. No significant changes in \( VO_{2\text{max}} \), ventilatory threshold, or onset of blood lactate occurred over an eight to ten-week season. Peak anaerobic power, assessed with a Wingate test, declined significantly over the season \((p=0.006)\), and runners rated the last race as significantly more difficult than the first race of the season \((p=0.04)\). The participants were the eight fastest runners at the team and achieved an average \( VO_{2\text{max}} \) of 71.9 ml/kg/min \((67-80 \text{ ml/kg/min})\), indicating that they were highly trained athletes. This study suggests that a cross-country season may not elicit quantifiable aerobic adaptations, specifically in highly trained distance runners; however, a season of training and competition may cause a decrease in anaerobic power and an increase in the perceived difficulty of racing. Athletes competed in an 8-km race every other week during the study, yet this data was not reported; thus, it is unclear
if improvements in race performance were achieved independent of significant physiological changes.

Literature also suggests that race performance improvements are possible, independent of increases in VO_{2max}. Acevedo and Goldfarb (1989) studied competitive male long-distance runners (n=7; 22.4 ± 1.3 yrs) averaging 50-65 miles/wk during the study. Over an eight-week training program, participants completed three weekly high-intensity, interval-based runs and three to four independent weekly runs. VO_{2max} was assessed before and after training, using a continuous progressive treadmill test in which the speed was kept constant and the grade increased by 2% every two minutes. No significant differences in relative VO_{2max} were found between pre- and post-training (65.30 ± 2.35 to 65.79 ± 2.39 ml/min/kg); however 10-km race time significantly decreased from pre- to post-training (35:27 ± 0.58 to 34:24 ± 1:13), and run time to exhaustion increased by an average of 4 minutes (p < 0.05). Lactate concentration was significantly lower at 85% and 90% of VO_{2max} (p < 0.05) and was significantly correlated with the improvements in 10-km race performance. This study suggests that increases in VO_{2max} may not be necessary for increases in performance; rather, increased training intensity and reduced plasma lactate may have led to improvements in endurance performance.

Similarly, Berg et al. (1995) found that improvements in VO_{2max} may not occur over a cross-country season in collegiate athletes. Female collegiate cross-country runners (n=7; 19.4 ± 1.2 yrs) were studied over one year of training which included a competitive cross-country season. Training included three days of high-intensity interval training runs and three alternating days of recovery runs. VO_{2max} was assessed through an
incremental treadmill protocol in which speed was increased every 3 minutes. Once a speed of 14.46 km/hr was reached, the speed remained constant and grade was increased by 2% each minute until volitional exhaustion. Significant changes were observed in time spent running at VO$_{2\text{max}}$ ($t = -2.79; p=0.03$) and 5-km performance time ($t = -2.61; p=0.04$), such that running time at VO$_{2\text{max}}$ increased and 5-km race time decreased. VO$_{2\text{max}}$ increased by 0.9% (53.4 ml/kg/min to 53.9 ml/kg/min); however, this increase was not significant ($p=0.62$). Peak treadmill grade was also highly correlated with 5km run time ($r = -0.925; p=0.01$) and this variable accounted for 85.6% of the variance in 5-kilometer race performance.

Berg et al. (1995) further illustrated this concept by comparing the performance of two female runners in the study with nearly identical VO$_{2\text{max}}$ values but different 5-kilometer race times. The faster runner achieved a greater peak grade at her VO$_{2\text{max}}$. In contrast with previous studies (Baumann et al., 2012; Cunningham, 1985; Saunders et al., 2010) these results suggest that VO$_{2\text{max}}$ is not the primary determinant of performance in some athletes.

In conclusion, previous research does address the changes that occur in VO$_{2\text{max}}$ and anaerobic threshold in runners as a result of cross-country training; however, consensus on the association of these variables with performance varies. The characteristics of these previous studies are summarized in Table 1 (Appendix A). Changes may be highly dependent on initial training status, age, duration and intensity of training, and the specific population examined. Although race performance and VO$_{2\text{max}}$ may be related, these variables can also improve independently of one another. Some studies showed non-significant improvements in each of these variables; however, any
improvements have the potential to benefit the cross-country athlete. The conflicting results presented in previous literature also highlight the importance of studying other factors that contribute to cross-country athlete success and performance. This previous research pertaining to adaptations in VO$_{2\text{max}}$ and associations with performance is further condensed below (see Table 1).

**Dietary Intake and Body Composition**

**Dietary Intake**

Total energy (kcal) intake also plays a role in endurance athlete performance (Burke et al., 2007; Thomas et al., 2016). Daily guidelines for total kcal intake are specific to individual athletes, as recommendations are based on sex, height, weight, body composition, and physical activity level (Thomas et al., 2016). Between 3,000-3,200 kcal/day and 2,400 kcal/day are recommended for physically active (≥3 miles of walking/day) men and women between ages 18-30, respectively (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). Due to the demands of training, athletes require a daily caloric intake that exceeds these recommendations (Thomas et al., 2016). Six to ten grams of carbohydrate per kilogram of body weight and 1.2-1.7 grams of protein per kilogram of body weight are recommended for the endurance athlete (Manore, Barr, & Butterfield, 2000). Thus, athletes should be consuming approximately 65% of calories from carbohydrate, 15% from protein, and 20% from fat (Manore et al., 2000). Recommendations are higher for athletes than for the general population, because athletes require increased carbohydrate to maintain glycogen stores (Costill et al., 1981) and increased protein to support skeletal muscle repair from training and increases in lean body mass (Lemon, 1996).
**Body Composition**

Body composition (fat mass and fat-free mass) also influence endurance athlete performance (Berg, 2003; Loucks, 2007; Thomas et al., 2016). Distance runners are typically characterized by lower levels of body fat and higher levels of lean mass, as these factors allow for more economical running behavior (Burke, et al., 2007) and improved thermoregulatory capacity (O'Connor & Slater, 2011). Lower body mass also allows the endurance athlete to demonstrate lower ground reaction forces (Berg, 2003). This helps to attenuate the high forces that running exerts on the body, allowing the endurance athlete to better endure the high mileage and intensity of their sport (Berg, 2003).

**Consequences of Caloric Insufficiency**

Despite increased energy (kcal) requirements, previous research indicates that athletes frequently consume insufficient calories (Hinton et al., 2004; Nutter, 1991; Shriver, Betts, & Wollenberg, 2013; Tanaka, Tanaka, & Landis, 1995; Thomas et al., 2016). Athletes may be unaware of deficits in total energy (kcal) intake; however, some may purposefully restrict calorie intake to alter body composition or maintain a low body weight (Loucks, 2007). Additionally, the body image of athletes may be negatively affected by participation in sport (Selby, Weinsten, & Stewart, 1990). The desire of athletes to lose weight may be due to outside pressure from coaches or to unrealistic personal expectations (Beals & Manore, 1994; Manore, Barr, & Butterfield, 2000). Ultimately, athletes may engage in unhealthy eating and exercise behaviors under the
assumption that this will improve performance (Benson, Gillien, Bourdet, & Loosli, 1985; Loucks, 2007). Considering this, it is unsurprising that athletes are at increased risk for eating disorders (Wilmore, 1991) and sub-clinical eating disorders (Beals & Manore, 1994). In a sub-clinical eating disorder, athletes may engage in disordered eating behaviors or display distorted body image, fear of weight gain, excessive preoccupation with weight, or engage in self-induced purges and binges, without meeting the specific criteria for an eating disorder (Beals & Manore, 1994).

The energy (total kcal) deficit from excessive exercise or calorie restriction can lead to negative health consequences (Beals & Manore, 1994; Loucks, 2007; Thomas et al., 2016). Relative Energy Deficiency in Sport (RED-S) (Mountjoy et al., 2014) is caused by energy (kcal) deficiency and describes the harmful effects of severe caloric restriction in athletes (Mountjoy et al., 2014). Specifically, RED-S refers to the impaired physiological function of various body systems, including decreased metabolic rate, bone health, immunity, protein synthesis, cardiovascular health, and, in females, menstrual functions (Mountjoy et al., 2014). Additionally, RED-S includes psychological disturbances associated with caloric restriction (Mountjoy et al., 2014). Additional consequences of inadequate caloric intake include lack of energy for competition, inability to replace glycogen stores, lack of protein for tissue building and repair, and micronutrient deficiency, leading to impaired metabolism and body homeostasis (Beals & Manore, 1994). Restricted calorie consumption may also suppress bone formation, which may eventually lead to osteoporosis (Loucks, 2007). Severe calorie restriction is also associated with psychological disturbances like depression and clinical eating disorders, such as anorexia nervosa and bulimia nervosa (Mountjoy et al., 2014).
Ultimately, optimal energy (kcal) intake and body composition (fat mass and fat-free mass) play a key role in enhancing athletic performance. The caloric deficits observed in many athletes, however, indicate that this topic deserves further exploration. Previous research examines the consequences of energy (kcal) deficits (Beals & Manore, 1994; Mountjoy et al., 2014), changes in energy (kcal) intake over a season (Clark, Reed, Crouse, & Armstrong, 2003), and caloric sufficiency in athletes (Niekamp & Barr, 1995; Nutter, 1999).

**Adaptations in Body Composition and Associations with Performance**

Previous research has examined training-induced changes in body composition (fat mass and fat-free mass) in athletes over a competitive season. Such changes may be influenced by sex, sport, and duration of training. Some research indicates that no significant changes in body composition (fat mass and fat-free mass) are observed in athletes in response to training. Using skinfold measurements, Baumann and Wetter (2010) found no significant changes in percentage of fat mass or fat-free mass over a cross-country season in collegiate cross-country runners. Niekamp and Barr (1995) assessed changes in body composition in male collegiate cross-country runners (n=12) over a 12-week cross-country season. Using hydrostatic weighting, they found that, although body weight increased significantly (64.6 ± 3.9 to 66.1 ± 4.2 kg; p<0.05), no significant increases in fat-free mass or fat mass were seen. Similarly, Berg et al. (2005) also estimated body fat percentage in female collegiate cross-country athletes through hydrostatic weighting. Body fat percentage decreased over a season (17.4% ± 3.6 to 15.9% ± 3.4); however, this decrease did not reach statistical significance (p=0.65). A negative correlation between body fat and 5-km race performance was found in female
collegiate runners ($r=-0.82$, $p=0.05$); such that, as body fat percentage decreased, running performance improved (22.1 min $\pm$ 1.3 to 21.1 $\pm$ 1.6 min) (Berg et al., 2005).

Stanforth et al. (2014) assessed body composition over three years in female NCAA-D1 athletes ($n=212$) from various sports (basketball, soccer, swimming, track, and volleyball) using the dual-energy absorptiometry (DEXA). Over three years, body mass (kg) increased significantly in basketball players ($n=38$; 75.7 $\pm$ 1.1 to 77.9 $\pm$ 1.2) and volleyball players ($n=26$; 70.5 $\pm$ 1.2 to 71.9 $\pm$ 1.4; $p<0.05$). Lean mass (kg) increased significantly in swimmers ($n=52$; 49.7 $\pm$ .07 vs. 50.3 $\pm$ 0.7) and volleyball players (51.9 $\pm$ 0.8 to 53.7 $\pm$ 0.9) ($p<0.05$). Percentage of body fat increased significantly in basketball players (25.8 $\pm$ 0.8 to 27.5 $\pm$ 0.9; $p<0.05$). These results indicate that the body composition of a student-athlete may change during their college career; however, changes may require a multi-year time frame. In addition, specific changes in body composition (fat mass and fat-free mass) may be dependent on the specific sport and the training associated with that sport. Additionally, the tool used to assess changes in body composition may contribute to the contradictory findings.

Previous research is conflicted on the specific association between body composition and performance in endurance athletes. Legaz and Eston (2005) assessed changes in body composition and performance over three years in elite sprint trained ($n=13$; 5 females) and endurance trained ($n=24$; 8 females) athletes. Average age was not reported. The race times recorded at the beginning and end of the three-year study were used to determine changes in race performance.

Across both sprint trained and endurance trained runners, significant improvements in race performance were seen each year for three years ($p < 0.001$)
Across all runners, body weight (kg) remained constant; however, runners showed a significant decrease in the sum of six skinfold measurements (mm) after three years of training (p=0.028). Across all athletes, after three years of training, improvements in racing performance were related to decreases in skinfold measurements in endurance runners. Specifically, as racing performance improved, estimated body fat decreased (r = -0.66, p<0.001).

Additionally, Legaz and Eston (2005) classified all runners into categories based on their race time, such that the more elite Class A athletes (n=18) achieved faster racing times than the Class B runners (n=19). When athletes were assessed in this manner, the authors found no significant changes in race performance or skinfold thickness in Class A runners over the three-year study. Class B runners, however, demonstrated significant improvements in race performance (p < 0.0001) and a decrease in sum of skinfolds (p=0.003) during the study. These results support the work of Arrese et al. (2005), indicating that improvements in both performance and body composition may be due to training status, with less trained individuals showing greater adaptations to training. These findings also support the results of Stanforth et al. (2014), indicating that adaptations in body composition may occur only over a multi-year time frame. Additionally, these results support the work of Berg et al. (1995), demonstrating that decreases in body fat percentage are related to improved racing performance in runners.

Similarly, Bale, Bradbury, & Colley (1986) assessed the relationship between body composition and 10-km run performance in male distance runners (n=60) training for a national 10-km road race. Participants were divided into elite, good, and average groups based on their best times for the 10km distance. Elite runners had significantly
more running experience (8.1 ± 2.2 vs. 5.2 ± 2.2 vs. 3.3 ± 1.8 yrs) and weekly mileage (67.8 ± 6.2 vs. 57.5 ± 7.5 vs. 38.1 ± 13.2) than good and average runners (p < 0.05). Skinfold measurements significantly decreased as ten-km performance increased (p < 0.05). *Elite* runners had significantly lower total skinfold measurements and percent body fat than *good* and *average* runners (p < 0.05). These results support the work of Legaz and Eston (2005), demonstrating that a lower body fat percentage is related to superior racing performance. In contrast, Knechtle, Knechtle, Schulze, and Kohler (2007) found no significant association between body fat percentage and racing performance. The authors estimated body composition with skinfold measurements in male ultra-endurance runners (n=19; 46.2 ± 9.6 yrs). Knechtle et al. (2007) found no significant association between body fat percentage (13.1% ± 3.3) and 1200 km racing performance in this population. These differences may be due to the variation in the populations studied.

In conclusion, previous research is conflicted on the associations between body composition (fat mass and fat-free mass) and performance. Additionally, training-induced changes in fat mass and fat-free mass may only occur over a multi-year time frame and may be unique to the specific sport.

**Dietary Intake and Associations With Race Performance**

**Cross-sectional Studies**

Inadequate energy (kcal) intake has been shown to impair performance in athletes; thus, previous research has assessed dietary adequacy in athletes during a competitive season. Hinton et al., (2004) assessed total kcal and macronutrient intake in male and female NCAA D-1 athletes (n=250; 180 males) from various sports. The Youth
Assessment Questionnaire from Rockett, Wolf, and Colditz (1995), a validated food frequency questionnaire, was used to collect self-reported data. The joint position stand of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine was used to estimate athlete energy (kcal) needs. Males consumed fewer calories than recommended (2447 ± 1053 vs. 2900 kcal); however, females, appeared to meet recommendations (2141 ± 781 vs. 2200 kcal). Sixty-one percent of female athletes (n=102) reported wanting to decrease their body weight by at least 2.3 kg to improve performance. Twenty-eight percent of female athletes (n=46) reported restricting dietary fat intake, and 23.9% of female athletes (n=38) reported restricting dietary carbohydrate intake to lose weight. This study indicates potential differences between energy (kcal) consumption in each sex. This study also provides evidence that female athletes may attempt to lose weight to improve performance, regardless of whether this behavior is warranted.

In contrast, Webber et al. (2015) found inadequate energy (kcal) intake in female athletes and adequate energy (kcal) intake in male athletes. They assessed dietary intake in collegiate male (n=48) and female (n=90) from various sports (gymnastics, swimming, diving, soccer, basketball, and volleyball). The 2005 Dietary Guidelines for Americans were used to estimate recommended energy (kcal) intake for the athletes. These recommendations were compared with athlete self-reported caloric intake from the Block 2005 Food Frequency Questionnaire and Healthy Eating Index 2005. Males consumed more calories than recommended (3616 vs. 3000 kcal) and females consumed fewer calories than recommended (1867 vs. 2400 kcal). Although there appear to be differences between recommended energy (kcal) intake and actual energy (kcal) intake, statistical
analyses were not conducted on this data; therefore, it is impossible to determine if results are statistically significant.

Shriver et al. (2013) found similar insufficiencies, using a multiple-pass 24-hour recall interview and 3-day food record to estimate total kcal consumption of female NCAA D-1 college athletes (soccer, basketball, cross-country, and track and field) \((n=45)\). Resting metabolic rate was estimated through the Cunningham (1980) equation; body composition was assessed through DEXA; self-reported physical activity data was gathered in conjunction with the dietary recalls. This information was used to estimate average daily calorie needs in athletes. Average total kcal intake \((1,939 \pm 604 \text{ kcal/day})\) was significantly lower than estimated energy needs across 91% \((n=41)\) of athletes \((p<.001)\). No significant differences in energy (kcal) intake were seen between different sports \((p>0.05)\), supporting the work of Hinton et al. (2014) which suggests that dietary inadequacy is an issue across student-athletes from various sports.

**Longitudinal Studies**

Due to fluctuations in training, and, consequentially energy expenditure, energy (kcal) needs will vary for athletes across a competitive season. Previous research highlights changes in energy (kcal) intake across a cross-country season. Clark, Reed, Crouse, and Armstrong (2003) examined dietary intake of NCAA D-1 female soccer players \((n=14)\) pre- and post-season through three-day dietary recalls and an interviewer led multi-pass 24-hour dietary recall. Basing recommendations on Dietary Reference Intakes published by the Food and Nutrition Board of the Institute of Medicine, authors estimated that athletes should be consuming between 2300-2550 kcal/day during pre-season and 1800-2000 kcal/day during the post-season. Using three-day dietary recalls,
Clark et al. (2003) determined that total daily energy (kcal) intake was significantly greater during the pre-season (2290 ± 310 kcal) compared to the post season (1865 ± 530 kcal) (p = .0012). Athletes met the recommended guidelines for calorie consumption across the season. Total grams of carbohydrate (p = 0.005), grams of protein (p = 0.0001), and grams of fat (p < .0001) were significantly greater from pre- to post-season. This study indicates that some collegiate athletes consume sufficient calories during the pre- and post-season and are able to adjust their diet to meet the varying energy demands of the season.

Hassapidou and Manstrantoni (2001) also found inadequacies in elite female athletes (n=35; 18-26 yrs) from various sports (volleyball, middle distance runners, swimmers, ballet dancers) during training and competition. Seven-day dietary recalls and self-reported physical activity questionnaires were used to estimate energy intake and expenditure. Total energy (kcal) intake was less than estimated energy expenditure during training (1816 ± 537 vs. 2311 ± 340) and competition (1868 ± 681 vs. 2338 ± 362), indicating that most athletes were not consuming sufficient calories during training and competition. Although inferential statistics were not conducted on data, these results appear to support previous studies (Shriver et al., 2013; Webber et al., 2015) which demonstrate that elite and collegiate female athletes do not consume sufficient calories during a competitive season.

Nutter (1991) assessed changes in total energy (kcal) intake and macronutrient distribution (carbohydrates, protein, fat) across a season in female cross-country runners (n=6). Seven-day dietary recalls were administered midway through the competitive season and approximately 6 weeks later, two weeks post-season. Three days were
selected for analysis, specifically, a weekend day, a practice day, and a competition day. Nutter reported that mean energy (kcal) intake for these athletes was less than recommended for their age and body weight; however, the basis for these recommended values was not reported as in previous studies (Clark et al., 2003; Hinton et al., 2004). Additionally, athlete physical activity levels were not considered; thus, it is likely that the discrepancies between energy (kcal) intake and expenditure were even greater than reported. Energy (kcal) intake did not change significantly from mid-season (1,664 ± 581 kcal) to post-season (1,463 ± 234 kcal). Most runners reported dieting in-season (n=4) and post-season (n=5); however, athlete weight was not reported; thus, it is impossible to determine if this behavior was warranted. This study supports the results of Hinton et al. (2004), indicating that female athletes often strive for weight loss over a season.

Similarly, Tanaka et al. (1995) also assessed dietary intake across a season in male and female collegiate cross-country runners (n=24). Four-day dietary records and physical activity logs were administered during training and competition. Males (n=14) averaged 16.0 ± 1.0 km/day during training and 14.6 ± 0.8 km/day during competition. Females (n=10) averaged 10.7 ± 0.6 km/day during training and 8.7 ± 0.5 km/day during competition. No significant difference in energy (kcal) intake were observed during training and competition phases in males (3,629.0 ± 223.4 vs. 3,542.1 ± 192.5 kcal) or females (1,988.3 ± 138.6 vs. 1,945.4 ± 161.1 kcal). Based on the Recommended Daily Allowance of 58 kcal/kg/day for exceptionally active men, male athletes appeared to consume sufficient calories during training and competition (55.7-57.1 kcal/kg/day). In contrast, female athletes consumed insufficient calories. They consumed an average of 36.0-36.4 kcal/kg/day, the amount recommended for females engaged in light or
moderate exercise. Similar to the study published by Webber et al. (2015), Tanaka et al., found that males consumed adequate calories during both phases, however, females did not meet the recommended daily allowance.

The caloric sufficiency of male athletes was also demonstrated by Niekamp and Baer (1995). They found that male collegiate cross-country runners \((n=12)\) consumed adequate calories during training and competition. Four-day dietary records were gathered at week two and week four of the 12-week season, and energy intake remained stable at these times. The first recall assessed dietary intake during the hardest training days, and the second record assessed competition and weekend intake. Energy expenditure was estimated by a laboratory estimation of resting energy expenditure and a measurement of energy expenditure during a typical workout. Dietary intake was averaged across each 4-day dietary recall, and no significant differences were found between total energy expenditure and total mean dietary intake \((3,439 \pm 244 \text{ kcal/day vs. } 3,248 \pm 590 \text{ kcal/day})\) \((p>0.05)\), meaning that energy (kcal) consumption was sufficient to support energy expenditure. These results indicate that male cross-country runners consume adequate calories to support the increased demands of their sport during a season of training and competition.

In conclusion, monitoring body composition and dietary intake during training and competition may be useful for monitoring athlete performance. Previous research has examined discrepancies between total energy (kcal) intake and estimated energy expenditure in athletes and has assessed changes in diet over a season. This research is conflicted about the adequacy of athlete dietary intake across a training season and the effects of a training season on body composition. Therefore, further research should
examine potential dietary inadequacies, associations between dietary intake and race performance, and seasonal dietary changes in cross-country athletes.

**Social Support in Student-Athletes**

In addition to the physiological and dietary factors which influence athlete performance, student-athletes face unique stress that differs from that of their peers (Cosh & Tully, 2015). This is due to various factors including the need to balance athletic performance with academic and social responsibilities (Cosh & Tully, 2015). Previous research indicates that athletes may prioritize athletic achievement above academic achievement, ultimately sacrificing this obligation in pursuit of athletic success (Cosh & Tully, 2014). Cosh and Tully (2015) also identified fatigue, coaches, scheduling, and financial concerns as additional stressors for athletes. The demands on student-athletes imply that this population must utilize all available resources to successfully navigate their athletic career (Cosh & Tully, 2015). Social support has been recognized as an asset for the student athlete (Adams, Coffee, & Lavallee; Cosh & Tully, 2015; Freeman & Rees, 2008). It has been shown to help athletes cope with the stress of competition (Cosh & Tully, 2015; Crocker, 1992), improve athletic performance (Freeman & Rees, 2008), and assist in the recovery process (Yang et al., 2010). Athletes receive social support from various sources; however, parents, coaches, teammates, and athletic trainers have been identified as primary sources of social support (Adams et al., 2015; Yang et al., 2010).
Previous research indicates that social support is critical in the rehabilitation process of injured student-athletes. Additionally, athletic trainers seem to play an important role in providing this social support. Using the modified Social Support Scale developed by Corbillon et al. (2008), Clement and Shannon (2011) assessed perceived social support from teammates, coaches, and athletic trainers of NCAA D-II and D-III injured student-athletes (n=49) and found that injured athletes were significantly more satisfied with the social support provided by athletic trainers than that provided by coaches and teammates (p = .001). Athletes reported that the support received from their athletic trainers was more satisfying, available, and provided a greater contribution to overall well-being than that of coaches and teammates.

In a similar study, Yang et al. (2010) assessed the relationship between social support and injury in NCAA D-I athletes (n=256, 160 males) from various sports (football, wrestling, baseball, gymnastics, golf, tennis, track, cross-country, golf, rowing, field hockey, and spirit squad) over eight months. The modified 6-item Social Support Questionnaire was used to quantify perceived social support at two time points. Injuries were defined as any reported incidence that required medical attention and limited full participation for more than one day. At baseline, when all athletes were uninjured, Yang et al. (2010) found that 96% of student athletes (n=246) identified family and friends as their primary sources of social support. Changes in perceived social support were then assessed in 42 injured athletes (23 men, 19 women) who completed a follow-up survey after 3 months. These injured athletes indicated significantly greater reliance on coaches (p = .003), athletic trainers (p < .0001), and physicians (p = .003) after injury. These
results suggest that the perceived source of social support changes after injury. Social support from teammates was not assessed in this study; however, this group may also play a role in the recovery process for injured student-athlete. In addition, this study supports the work of Clement and Shannon (2011), highlighting the importance of social support in injured student-athletes.

Bone and Fry (2006) also assessed associations between athletes’ perceptions of social support from their certified athletic trainers and the rehabilitation process. NCAA D-1 athletes (n=57; 35 men) from various sports (football, soccer, cheer/dance, volleyball, track/cross-country, men’s basketball, baseball, and golf) completed the Social Support Survey (Richman, Rosenfeld, & Hardy, 1993) and the Sports Injury Rehabilitation Beliefs Survey (Taylor & May, 1996) to determine athletes’ perception of social support and beliefs about rehabilitation. Significant correlations were found between perceived social support and rehabilitation beliefs in athletes who identified themselves as severely injured (n=28). Multiple regression analysis indicated that perceived social support explained more than 30% of the variance in rehabilitation beliefs in severely injured athletes. This may be because severely injured athletes must rely more on the support of athletic trainers than athletes with mild or moderate injuries. Thus, these results suggest that perceived social support plays a role in the process of the athlete returning to play.

Robbins and Rosenfield (2001) assessed student athlete (n=35) perceptions of social support from head coaches, assistant coaches, and athletic trainers before injury and during rehabilitation. Social support was assessed through a modified version of the Social Support Survey developed by Richman, Rosenfield, and Hardy (1993). Prior to
injury, no significant differences were found in satisfaction with support supplied by head coaches, assistant coaches, and athletic trainers ($p > 0.05$). However, after injury, athletes were more satisfied with the support received from athletic trainers than head coaches and assistant coaches ($p < .001$), suggesting that athletes reported that athletic trainers provided more social support than head coaches or assistant coaches during the rehabilitation process. These results support previous studies (Bone & Fry, 2006; Clement & Shannon, 2011; Yang et al., 2010), indicating the important role of social support in physical rehabilitation.

**Social Support and Mental Health**

Research also indicates a relationship between social support, depression, and motivation in student-athletes. Hagiwara, Iwatsuki, Isogai, Van Raalte, and Brewer (2017) assessed the relationship between social support from teammates and mental health problems in NCAA student athletes ($n=204$, 105 males). Provided and received social support was assessed using the Receiving and Providing Social Support Scales for Sports Teams (Hagiwara, Bryant, Benavides Espinoza, & Isogai, 2016). Mental health, specifically depression, was assessed using the Stress Response Scale for Athletes (Kemuriyama, 2013). No significant differences were found in social support or depression between male and female NCAA student-athletes. Received social support ($r = -0.38$) and provided social support ($r = -0.29$) were significantly negatively correlated with depression in female athletes but not in male athletes. This study suggests that social support is important for lowering depression in female athletes.

Social support may influence athlete motivation to continue participation in their sport. DeFreese and Smith (2014) assessed changes in perceived social support across a
competitive season in collegiate athletes \((n=46)\) from various sports (swimming, diving, and track and field). They also assessed whether social support contributed to burnout in athletes. Social support was assessed using the modified 6-item Social Support Questionnaire developed by Sarason, Sarason, Shearin, & Pierce (1987), and athlete burnout was assessed through the Athlete Burnout Questionnaire from Raedeke & Smith (2001). Athletes received questionnaires at four times over their competitive seasons. Social support was significantly negatively associated with burnout \((p < 0.05)\), suggesting that this factor influences athlete well-being.

**Social Support and Athletic Performance**

Social support may also impact athletic performance. Freeman and Rees (2008) studied the effects of social support on athletic performance in elite male golfers \((25.3 \pm 5.4 \text{ yrs}, n=123)\). Athletic performance was defined by number of shots taken during a game, with fewer shots indicating improved performance. Perceived and received support were assessed through a 16-item questionnaire designed by the authors. Athletes self-reported stress from competition pressure, technical game problems, and personal problems, as well as their perceptions of this stress. There was a significant main effect for stress upon performance \((R^2 = 0.13, b = 0.82, p < 0.01)\); however, above the effects of stress, there was also a significant main effect for perceived social support on performance \((R^2 = 0.08, b = -0.81, p < 0.01)\) such that higher perceived support was associated with better performance (Freeman & Rees, 2008). In addition, higher received support was also associated with better performance \((R^2 = 0.05, b = -0.68, p < 0.01)\). Ultimately, although stress was harmful to performance, there was a significant interaction between stress and social support, such that perceived support reduced the
negative effects of stress (Freeman & Rees, 2008). These results suggest that social support is influential in the athletic performance of athletes, making it an important construct to assess in this population.

Ultimately, social support is an important factor in the life of the student-athlete. This construct plays a role in the rehabilitation process, with the source of social support also being an important construct. Athletic trainers play a critical role at this stage, as they are largely responsible for the care and support of the athlete during injury and recovery. Social support has also been shown to be associated with improved performance, decreased stress, and decreased depression. The primary sources of social support in student-athletes may vary; however, teammates, coaches, family, and athletic trainers have been cited as valuable sources of social support. Additionally, male and female athletes may perceive and receive social support differently. There is a lack of research on how perceived social support changes in cross-country athletes over a competitive season, as well how this construct influences performance. This suggests that this area should be explored further.

**Conclusion**

Ultimately, maximal aerobic capacity, anaerobic threshold, body composition, dietary intake, and social support each play a role in the performance of the cross-country athlete. Physiological adaptations in VO$_{2\text{max}}$ and anaerobic threshold may occur over a season, and these adaptations may or may not occur concurrently with improvements in racing performance. Body composition (fat mass and fat-free mass) influences performance; however, previous research is conflicted on the changes that occur in this parameter in athletes. Additionally, despite the role that dietary intake plays in
performance, athletes demonstrate inadequate energy (kcal) intake to support the

demands of training and competition. Lastly, social support plays a role in the life of the student-athlete; however, longitudinal research on this construct is limited. Ultimately, little research has assessed longitudinal changes in these constructs concurrently over a competitive season. Therefore, research should continue to explore these areas in cross-country athletes and assess the effects of these variables on overall performance.
Chapter 3

Methods

Participants

Participants were male and female NCAA Division I athletes recruited from the Eastern Washington University cross-country team. Participants were between the ages of 18-25 years. The entire team was recruited for participation at the conclusion of the outdoor track season; however, participation was voluntary. The principal investigator also attended team meetings before the competitive season and after the final seasonal race for continued recruitment.

Instrumentation

All testing was performed in the Human Performance Laboratory at Eastern Washington University. All equipment was calibrated according to manufacturer instructions before each individual testing session. To ensure valid data, pre-testing instructions regarding exercise, food intake, fluid intake, and caffeine consumption were provided to participants. Adherence to these procedures was checked by self-report prior to testing.

Heart rate (bpm) was obtained using the FT1 Polar heart rate monitor (Polar Electro, Kempele, Finland). Peak aerobic capacity (VO\textsubscript{2peak} (ml\textper m\textsuperscript{2}kg\textsuperscript{-1}min\textsuperscript{-1}) was measured by way of an indirect calorimeter (ParvoMedics TrueOne\textsuperscript{®} 2400 Metabolic Cart Murray, Utah) interfaced with a treadmill (Trackmaster TMX425C, FullVision INC, Newton, KS). This system has been shown to be a valid (Bassett et al., 2001) and reliable (Crouter, Antezak, Hudak, DellaValle, & Haas, 2006) way to measure gas
exchange. Ventilatory threshold was obtained using the automated V-slope method (ParvoMedics TrueOne 2400, Salt Lake City, Utah). This method identifies ventilatory threshold as the point at which the VCO2 and VO2 regression lines intersect. The data points for these regression lines are determined using breath-by-breath analysis and the variance (residual sum of squares) of the data points.

A two-compartment model of body composition was assessed using the BOD POD® (COSMED USA Inc., Concord, CA, USA) to determine fat mass (kg, %) and fat-free mass (kg). This method has been shown to be a valid measure of fat mass (kg) and fat-free mass (kg) in university athletes from various sports (Ballard, Fafara, & Vukovich, 2004; Dixon, Deitrick, Pierce, Cutrufello, & Drapeau, 2005; Vescovi, Hildebrandt, Miller, Hammer, & Spiller, 2002).

Dietary intake data (kcal/day) was analyzed through the Automated Self-Administered 24-hour (ASA24®) Dietary Assessment Tool, version 2016, developed by the National Cancer Institute (Bethesda, MD). The ASA24® was modeled after the U.S. Department of Agriculture’s interviewer-administered Automated Multiple-Pass Method (AMPM), a validated tool (Moshfegh et al., 2008) used in the National Health and Nutrition Examination Survey (Thompson et al., 2014). These two methods have been shown to provide equivocal total kcal estimations (Kirkpatrick et al., 2014; Thompson et al., 2014). Further, the ASA24® has been shown to provide reliable reports of total kcal consumption when compared to true, weighed kcal intake (Kirkpatrick et al., 2014).

Perceived social support was assessed using the 16-item Perceived Available Support in Sport Questionnaire (PASS-Q) developed by Freeman et al. (2011). This tool has been validated in university students (Freeman et al., 2011) and has been previously
used to assess perceived social support in student athletes (Adams, Coffee, & Lavalle, 2015; Gabana, Steinfeldt, Wong, & Chung, 2017). Athletes self-recorded their weekly training load (total mileage, frequency, duration) in a Google Document. This practice had been previously established by the university cross-country coach, and the athletes were familiar with this process.

**Procedures**

Prior to participant recruitment, study approval was obtained from the Eastern Washington University Institutional Review Board for Human Subjects Research (Appendix A). The cross-country coach was contacted through an email requesting a meeting with athletes for the purpose of study recruitment (Appendix C). Potential participants were then recruited by the principal investigator at a team meeting during the pre-season, following the conclusion of the outdoor track season. The principal investigator read to the athletes from a script (Appendix D), describing the potential risks, benefits, and testing procedures of the study. Athletes were invited to ask any additional questions for clarification. Those who were eligible for sport participation during the cross-country season were invited to participate in the study. Athletes who consented to participate signed an informed consent (Appendix E) that described study procedures, risks associated with participation, the voluntary nature of the study, and their right to withdraw at any time without penalty. To ensure safety, athletes also completed a Physical Activity Readiness Questionnaire for Everyone (Appendix F) (Bredin, Gledhill, Jamnik, & Warburton, 2013) prior to study participation.

Testing occurred at three different time points during the cross-country season, corresponding to the pre-season (T₁), in-season (T₂), and post-season (T₃). These sessions
occurred at the conclusion of the outdoor track season (prior to the summer off-season), prior to the beginning of the cross-country racing season, and at the conclusion of the competitive cross-country season. Prior to each testing session, the principal investigator attended a team meeting to follow-up with recruitment. Athletes signed up for testing in a Google document owned by the principal investigator. Athletes were asked to allot 60-90 minutes for each testing session.

**Pretesting Instructions**

Athletes were permitted to continue their normal exercise routine but were asked not to perform any exercise on the day of testing. Athletes were instructed to avoid food, water, and caffeine for two hours prior to testing in accordance with American College of Sports Medicine (ACSM) guidelines for testing (Riebe, Ehrman, Liguori, & Magal, 2018). Athletes were instructed to arrive at the laboratory in appropriate exercise attire. Athletes were scheduled individually, reporting every half hour on their designated testing day.

**Dietary Intake**

Athletes began the testing session by completing the ASA24® dietary recall (Appendix G) on a laptop provided by the principal investigator. Athletes spent between 20 and 40 minutes on this recall. The principal investigator designated each athlete a specific username and password which provided each participant access to a unique ASA24® account. The ASA24® guided participants through a 24-hour dietary recall using an online dynamic user interface. Participants reported all food eaten in the previous day (24-hour) and answered detailed questions about the amount of food eaten and its method
of preparation. This allowed assessment of total daily kilocalorie (kcal) intake. All self-reported nutritional data remained confidential. Total kcal intake and sufficiency of kcal intake was assessed at three time points.

**Social Support**

Athletes completed an electronic questionnaire created with Google survey. This questionnaire included the 16-item PASS-Q survey (Freeman et al., 2011) (Appendix H). Participants reported their age, sex, and year in school. This survey required approximately 10 minutes to complete. All survey data remained confidential. Social support score was assessed at three time points and was associated with race performance.

**Body Composition**

Body composition was estimated with the BOD POD which estimates fat mass (kg, %) and fat-free mass (kg) using air displacement plethysmography. During the BOD POD test, men wore a form-fitting Speedo®, a Lycra®/Spandex-type swimsuit or compression shorts without padding. Women wore a form-fitting Speedo®, Lycra®/Spandex-type swimsuit or single layer compression shorts without padding and a jog bra. All participants were provided with a swim cap and instructed to remove all accessories (jewelry, eyeglasses, etc.) prior to testing. Height (cm) and weight (kg) were measured prior to the test. These tests required approximately 15 minutes. Body composition (fat mass and fat-free mass) was estimated at three time points and sufficiency of body fat percentage was assessed. Fat-free mass (kg) was associated with race performance at each time point.
**VO_{2\text{peak}} and Ventilatory Threshold**

VO_{2\text{peak}} was determined using open-circuit spirometry and breath-by-breath data collection. Prior to each test, the gas and flowmeter were calibrated according to the manufacturer’s instructions. Athletes were fitted with the Polar heart rate monitor and sat quietly for 5 minutes while resting heart rate was recorded. During this time, participants were familiarized with the Borg 1-10 RPE scale (Appendix I) (Borg, 1970), associated equipment, and reminded of the testing protocol. Following this, athletes were also fitted with the rubber mouthpiece connected to a two-way non-rebreathing valve, held in place by the head support. The nose clip was applied prior to the test.

Participants then began the graded exercise test on a treadmill, following a standardized protocol. The standardized protocol consisted of a two-minute warm-up in which participants ran for two minutes at 7.0 mph at a 0% incline. Participants began the test immediately following the warm-up. The treadmill speed increased to 7.5 mph, followed by an increase of 0.5 mph every minute until 10 mph was reached. Following this, treadmill incline was increased by 2% every minute until volitional exhaustion. This protocol is similar to those used to assess VO_{2\text{max}} in cross-country athletes in previous studies (Lambert & Costill, 1996; Plank et al., 2005; Saunders et al., 2010). Exercise heart rate and RPE were recorded at the end of each stage of the test. Pulmonary ventilation was continually measured throughout the test.

Breath-by-breath gas exchange data from all tests were transferred to a spreadsheet program (Microsoft Excel 16.0) for continued analysis. Based on the methods of previous studies (Astorino, Robergs, Ghiasvand, Marks, & Burns, 2000; Lamberts, 2014), all VO_{2} data were smoothed using a 15-breath rolling average. The
highest value obtained during the last minute of the test was reported as VO$_{2\text{peak}}$.

Ventilatory threshold was determined using the ParvoMedics’ automated detection of anaerobic threshold using the V-slope method. The data points for the regression lines (VCO$_2$ and VO$_2$) were calculated through the average of breath-to-breath data points over a set time interval.

Throughout the test, participants received verbal encouragement and were monitored for signs that they were nearing maximal effort. Upon test termination, the treadmill speed was decreased to 2.5 mph, incline was lowered to 0%, and athletes were instructed to walk for 3 minutes in accordance with ACSM testing guidelines (Riebe et al., 2018). Both VO$_{2\text{peak}}$ and ventilatory threshold were measured at three time points during the study and were associated with race performance.

**Training Log**

Athletes self-reported their weekly mileage, frequency, and duration of exercise and any additional physical activity in a Google Document (Appendix I). They began this practice during the pre-season (prior to the first testing session) and continued for the duration of the study. The cross-country coach, athletic trainer, and principal investigator had access to this document, and athletes were reminded to record weekly exercise volume each week by the cross-country coach.

**Race Performance**

Six cross-country races took place between August and November. Female athletes ran 4-km, 5-km, or 6-km races, and male athletes ran 6-km, 8-km, or 10-km races. Athlete race times were documented after each meet. Average time in the most
frequently raced distance was reported and associated with the dependent variables
(relative VO$_{2peak}$, ventilatory threshold, fat-free mass, and social support). Thus, average
6-km race time for females and average 8-km race time for males was used as the
measure of race performance in this study.

**Statistical Analyses**

Descriptive statistics were calculated for age, height, body mass, race times, and
all dependent variables: VO$_{2peak}$, ventilatory threshold, dietary intake (total kcal), fat-free
mass (kg), body fat (%), and perceived social support. Inferential statistics were
calculated using SPSS v25.0 (IBM Corp, Armonk, NY, SA) with the alpha level set at $p < 0.05$. Repeated measures ANOVAs were used to test for significant differences in peak
aerobic capacity, ventilatory threshold, dietary intake, body composition, and perceived
social support across three time points. When data was not obtained at all three time
points, a within-subjects t-test was used to assess potential significant differences in these
dependent variables across two time points. Pearson’s product-moment correlation, or
Pearson’s $r$, was used to test for potential linear associations between race performance
and individual dependent variables. If significant correlations were found, linear
regression was used to determine significant predictors of race performance.
Chapter Four

Results

Pilot Testing

The incremental treadmill protocol was pilot tested on a highly active 27-year old male. The participant exercised until volitional exhaustion, concluding the test with an RER value >1.10 and a final heart rate within 10 beats per minute of age-predicted maximal heart rate, with maximal heart rate estimated using the Fox equation (i.e., 220-age) (Fox, Naughton, & Haskell, 1971; Poole, Wilkerson, & Jones, 2008). This participant reached volitional exhaustion between eight and twelve minutes. These values have been used as criteria indicating attainment of true maximal aerobic capacity in previous research (Astorino et al., 2000; Astorino et al., 2004; Gibbons, et al., 1997). These criteria supported the validity this treadmill protocol in the assessment of peak aerobic capacity in highly active cross-country runners.

Participants

Following IRB approval, current, eligible, male and female cross-country runners were invited to a pre-season recruitment meeting by the principal investigator. It was not possible to recruit incoming freshman prior to the start of the regular season. During the recruitment meeting, the study was described, including the protocol, equipment, proposed benefits, and potential risks. Potential participants were provided an opportunity to ask questions. All who volunteered for participation provided informed consent.
Participants were asked to report for testing at three time points, corresponding to pre-season (T1), in-season (T2), and post-season (T3). At T1, eleven males completed testing. After T1, three males chose to discontinue their participation. At T2, ten males completed testing, including two additional incoming male freshmen. After T2, five males discontinued due to injury. At T3, five males completed testing. (Figure 1)

At T1, two females completed testing, however, after T1, one female discontinued study participation due to injury. Thus, during the pre-season, statistical analyses were not conducted on this individual female. At T2, eight females completed testing, with seven additional incoming female freshmen. After T2, five females discontinued due to illness or injury. At T3, three females completed testing. Participant participation is further described in Figure 1. Results are reported for cross-country runners who tested at T1 and T2, at T2 and T3, and at T1-T3. (Figure 1)
Figure 1. Pre-Season, In-Season, and Post-Season Participation

Upon arrival for testing, adherence to pre-testing instructions was assessed by athlete self-report. Athletes first completed the dietary recall, social support survey, and demographic information. They then completed the body composition assessment. Lastly, they completed the incremental treadmill test. The testing session lasted between 60 and 90 minutes for each athlete. Characteristics of male and female participants at each time point are presented in Table 1.

Table 1. Participant Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>T1 (Pre-Season) (n=9)</th>
<th>T2 (In-Season) (n=10)</th>
<th>T2 (In-Season) (n=8)</th>
<th>T3 (Post-Season) (n=5)</th>
<th>T3 (Post-Season) (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>179.00 ± 4.50</td>
<td>179.07 ± 5.36</td>
<td>170.97 ± 4.14</td>
<td>178.80 ± 6.60</td>
<td>170.97 ± 4.14</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>70.83 ± 4.65</td>
<td>70.90 ± 4.8</td>
<td>58.10 ± 5.67</td>
<td>65.08 ± 8.10</td>
<td>58.23 ± 7.07</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>20.00 ± 0.00</td>
<td>19.70 ± 0.82</td>
<td>18.67 ± 1.15</td>
<td>19.60 ± 1.10</td>
<td>18.67 ± 1.15</td>
</tr>
<tr>
<td>XC Experience (yr)*</td>
<td>1.00 ± 0.00</td>
<td>1.10 ± 0.88</td>
<td>1.00 ± 1.73</td>
<td>1.20 ± 1.10</td>
<td>1.00 ± 1.73</td>
</tr>
</tbody>
</table>

*XC Experience: years of collegiate cross-country experience

The metabolic cart (ParvoMedics TrueOne 2400, Salt Lake City, Utah) was calibrated prior to each test according to manufacturer’s guidelines, including both gas and flowmeter calibrations. The system was set to collect breath-by-breath data. Participants were fitted with the required equipment, including a heart rate monitor.
Cross-country runners completed the incremental exercise test to exhaustion, with all tests lasting between eight and twelve minutes. Rate of perceived exertion (RPE) was recorded every minute of the test. Breath-by-breath gas exchange data from all tests were exported to Excel (Microsoft Excel 16.0) for analysis. Based on the methods of previous studies, VO₂ data were smoothed using a 15-breath rolling average, and the highest value recorded during the last minute of exercise was reported as the relative VO₂peak (ml·kg⁻¹·min⁻¹) for each athlete (Astorino et al., 2000; Lamberts, 2014). Ventilatory threshold was determined using the automated V-slope method (ParvoMedics TrueOne 2400, Salt Lake City, Utah). Ventilatory threshold is reported in both absolute (ml/kg/min) and relative (%VO₂peak) terms. At each testing session, descriptive statistics were calculated for age, height, body mass, and all dependent variables: VO₂peak, ventilatory threshold, dietary intake (total kcal), fat-free mass (kg), body fat (%), and perceived social support and are presented in Table 2.
Table 2.

**Comprehensive Athlete Assessment**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>T₁ (Pre-Season) (n=9)</th>
<th>T₂ (In-Season) (n=10)</th>
<th>T₂ (In-Season) (n=8)</th>
<th>T₃ (Post-Season) (n=5)</th>
<th>T₃ (Post-Season) (n=3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>VO₂peak (ml·kg⁻¹·min⁻¹)</td>
<td>64.13 ± 2.66</td>
<td>65.60 ± 1.28</td>
<td>57.37 ± 1.02</td>
<td>68.12 ± 4.36</td>
<td>57.07 ± 3.23</td>
</tr>
<tr>
<td>VT* (ml·kg⁻¹·min⁻¹)</td>
<td>53.91 ± 4.34</td>
<td>53.32 ± 6.17</td>
<td>48.18 ± 0.82</td>
<td>56.06 ± 8.77</td>
<td>46.53 ± 8.60</td>
</tr>
<tr>
<td>VT* (%VO₂peak)</td>
<td>84.33 ± 1.00</td>
<td>81.33 ± 1.01</td>
<td>84.00 ± 0.02</td>
<td>82.00 ± 8.63</td>
<td>82.00 ± 0.17</td>
</tr>
<tr>
<td>Fat-Free Mass (kg)</td>
<td>60.81 ± 8.04</td>
<td>62.24 ± 7.37</td>
<td>47.14 ± 8.28</td>
<td>61.83 ± 8.77</td>
<td>48.83 ± 5.72</td>
</tr>
<tr>
<td>Fat Mass (kg)</td>
<td>4.92 ± 2.61</td>
<td>3.86 ± 2.77</td>
<td>11.49 ± 3.61</td>
<td>2.67 ± 2.04</td>
<td>9.40 ± 1.40</td>
</tr>
<tr>
<td>Energy Intake (kcal/day)</td>
<td>2302.10 ± 593.23</td>
<td>2066.77 ± 327.82</td>
<td>1627.37 ± 148.10</td>
<td>3643.20 ± 776.48</td>
<td>2321.38 ± 669.50</td>
</tr>
<tr>
<td>Social Support</td>
<td>10.75 ± 3.85</td>
<td>11.92 ± 1.38</td>
<td>13.42 ± 1.53</td>
<td>12.1 ± 1.65</td>
<td>14.50 ± 1.50</td>
</tr>
</tbody>
</table>

*VT: Ventilatory Threshold

**Seasonal Changes in Males**

**Pre-Season to In-Season**

Three male participants completed testing exclusively at T₁ and T₂. Paired sample t-tests revealed no significant differences in peak aerobic capacity, relative ventilatory threshold, energy intake, body fat percentage, fat free mass (kg), or social support between T₁ and T₂ (p > 0.05). (See Table 2 and Figures 2-3).
Recommended total daily energy needs were determined through an estimation of resting metabolic rate (RMR) and daily activity levels. RMR was determined using the equation developed by Nelson, Weinsier, Long, & Schultz (1992). This equation uses an estimation of fat mass and fat free mass to predict resting energy expenditure.

Participants were categorized as ‘very active’ based on Institute of Medicine guidelines (Brooks, Butte, Rand, Flatt, & Caballer, 2004). This designation is given to individuals who expend the energy equivalent to walking 17 miles per day at the rate of 3-4 miles per
hour (Brooks et al., 2004). This categorization equates to a physical activity coefficient of 1.7 – 2.2, which is used in the estimation of total energy expenditure (TEE). The final prediction equation reads as follows:

\[
\text{Estimated TEE} = \text{Estimated RMR} \times \text{Physical Activity Coefficient}
\]

Thus, TEE provides an estimation of the total energy required to support both resting metabolism and physical activity (i.e., recommended energy intake). In addition to testing for changes in energy intake across the season, paired sample t-tests were also used to assess potential significant differences between recommended daily energy intake and self-reported daily energy intake. Analysis revealed a significant difference between recommended energy intake (3538.00 ± 273.18) and self-reported energy intake (2212.26 ± 692.42) at T₁ \((t_{2} = 4.35, p = 0.049)\). A significant difference between recommended energy intake (3533.00 ± 273.18) and self-reported energy intake (1952.62 ± 288.13) was also observed at T₂ \((t_{2} = 14.78, p = 0.005)\). At T₁ and T₂, males failed to consume sufficient calories, with an average energy deficit of 1051 and 1257 kcal/day, respectively (Figure 4).

*significant difference between recommended and reported calories at each time point \(p<0.05\)
Figure 4. Comparison of Recommended Energy Intake to Reported Energy Intake

Pre-Season, In-Season, and Post-Season

Five males completed testing at all three time points. Participant characteristics are presented in Table 1. Repeated measures ANOVAs revealed no significant change in relative VO$_2$peak, relative ventilatory threshold, fat-free mass (kg), fat-mass (%) or social support across the three time points. (See Table 2 and Figures 5-7).

Figure 5. Relative Peak Aerobic Capacity and Ventilatory Threshold

Figure 6. Perceived Social Support Scores
In addition to testing for differences in energy intake across time, reported total daily energy intake was also assessed for adequacy in relation to recommended daily energy intake. Paired sample t-tests revealed no significant difference between recommended and reported energy intake at any time point in this sample (p > 0.05). (Figure 7).

**Figure 7.** Comparison of Recommended Energy Intake to Reported Energy Intake

### Body Fat Percentage in Males

Body fat percentage results were categorized into risky, ultra-lean, and lean categories based on body fat rating information from previous research (Flegal et al., 2009; Riebe, Ehrman, Liguori, & Magal, 2018)
Figure 8. Body Fat Ratings Across the Season

Seasonal Changes in Females

In-Season to Post-Season

Females who completed pre-season testing discontinued their participation; thus, pre-season data is not available for this group. Further, no females tested at all three time points. Female participants (n=3) completed testing at T$_2$ and T$_3$ (Table 1). Paired sample t-tests revealed no significant differences in peak aerobic capacity, relative ventilatory threshold, energy intake, fat-mass (%), fat-free mass (kg), or perceived social support between T$_2$ and T$_3$ (p > 0.05). Results are presented in Table 2 and Figures 4-6.
Paired sample t-tests were used to assess potential significant differences between recommended and self-reported total daily energy intake at each time point. Analysis revealed significant differences between recommended energy intake (2602.67 ± 239.29) and self-reported energy intake (1627.37 ± 148.09) at T₂ (t(7) = 15.33, p = 0.004) but not at T₃ (p >0.05). At T₂, all females failed to consume sufficient calories, demonstrating an average energy deficit of 975 kcal/day (Figure 6).

*significant difference between recommended and reported calories (p<0.05)
**Figure 11.** Comparison of Estimated Energy Intake to Reported Energy Intake

**Body Fat Ratings in Females**

Body fat levels were categorized into risky, ultra-lean, lean, and moderately lean categories based on guidelines from previous research (Flegal et al., 2009; Riebe et al., 2018). Results are further described in Figure 12.

![Body Fat Ratings Across the Season](image)

**Figure 12.** Body Fat Ratings Across the Season

**Race Performance**

Race performance was defined by average race time (min) in a set distance across the season. Males competed in a total of six races. Of these, one was 5.75 kilometers, four were eight kilometers, and one was 10-kilometers. Females competed in a total of six races. Of these, one was four kilometers, two were five kilometers, and three were six kilometers. The average race time for the most frequently raced distance was used as each athlete’s race performance index. Thus, average 8-km and 6-km race time were used as the race performance index for males and females, respectively. Repeated measures
ANOVAs revealed no significant difference between 8-km race times and 6-km race times in males and females, respectively.

Males averaged an eight-km race time of 27.36 ± 1.00 minutes in the pre-season (n=9), 27.31 ± 0.96 min during the in-season (n=10), and 26.85 ± 1.06 minutes (n=5) during the post-season. Females averaged a 6-km race time of 23.02 ± 1.22 minutes in the in-season (n=8) and 22.89 ± 0.31 minutes during the post-season (n=3). A repeated measures ANOVA revealed no significant differences in times between these races in males or females.

A Pearson product-moment correlation coefficient was used to test for a significant linear relationship between VO2peak, ventilatory threshold (%VO2peak), fat-free mass (kg), and perceived social support score with race performance in males and females at pre-season (T1), in-season (T2), and post-season (T3).

**Association of Participant Characteristics with Performance**

**Males**

In males, 8-km race time was not significantly associated with relative VO2peak, ventilatory threshold (%VO2peak), fat-free mass, or social support during the pre-season or in-season (p > 0.05). A significant association was found between fat-free mass (kg) and race time (r = .95, p = .02) during the post-season.
Table 3.

Association of Participant Characteristics with Performance in Males

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Pre-Season (n=9) r</th>
<th>In-Season (n=10) r</th>
<th>Post-Season (n=5) r</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO\textsubscript{2peak} (mL\textsuperscript{-1}kg\textsuperscript{-1}min\textsuperscript{-1})</td>
<td>r = -.42</td>
<td>r = -.55</td>
<td>r = .06</td>
</tr>
<tr>
<td>VT (%VO\textsubscript{2peak})</td>
<td>r = -.41</td>
<td>r = -.27</td>
<td>r = -.02</td>
</tr>
<tr>
<td>Fat-Free Mass (kg)</td>
<td>r = -.09</td>
<td>r = .20</td>
<td>r = -.95*</td>
</tr>
<tr>
<td>Social Support Score</td>
<td>r = .33</td>
<td>r = .07</td>
<td>r = .15</td>
</tr>
</tbody>
</table>

*Significant association with race time, p = .02

Females

In females, 6-km race time was significantly associated with relative VO\textsubscript{2peak} (r = .95; p = <0.001) during the in-season. No significant associations were found between relative VO\textsubscript{2peak}, ventilatory threshold (% fat-free mass (kg), or social support score with race time during the post-season (p > 0.05).
Table 4.

*Association of Participant Characteristics with Performance in Females*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>In-Season</th>
<th>Post-Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_{2\text{peak}}$ (ml·kg$^{-1}$·min$^{-1}$)</td>
<td>$r = -.95^*$</td>
<td>$r = -.52$</td>
</tr>
<tr>
<td>VT (% VO$_{2\text{peak}}$)</td>
<td>$r = .37$</td>
<td>$r = .97$</td>
</tr>
<tr>
<td>Fat-Free Mass (kg)</td>
<td>$r = -.29$</td>
<td>$r = .57$</td>
</tr>
<tr>
<td>Social Support Score</td>
<td>$r = -.34$</td>
<td>$r = .64$</td>
</tr>
</tbody>
</table>

*$^*$significant predictor of six-kilometer race time in females ($r = .95$; $p < .001$)
Chapter 5

Discussion

This study assessed changes in relative VO$_{2\text{peak}}$, ventilatory threshold, energy intake, fat-mass, fat-free mass, and perceived social support in collegiate cross-country runners across a single season and sought to determine their relationship with average race performance across this season. Over six months, athletes were tested three times, corresponding to pre-season, in-season, and post-season time points. Previous research has demonstrated that VO$_{2\text{peak}}$ (Jones & Carter, 2000) and ventilatory threshold (Caiozzo et al., 1982) are positively associated with race performance. It is also well established that total energy (kcal) intake influences the performance of the endurance athlete (Burke, Millet, & Tarnopolsky, 2007; Thomas et al., 2016), with insufficient caloric intake a precursor to health conditions such as Relative Energy Deficiency in Sport (Mountjoy et al., 2014). Lower levels of fat mass and higher levels of fat-free mass are characteristic of successful distance runners, as this body composition allows for more economical movement (Burke et al., 2007) and enhanced thermoregulatory capacity (O’Connor & Slater, 2011). Additionally, social support is recognized as an important resource for the student athlete due to the demands of sport participation (Cosh & Tully, 2015). This construct has been shown to benefit athletic performance (Freeman & Rees, 2008) and has positive effects on both physical (Berkman & Syme, 1979) and mental health (Aneshensel & Frerichs, 1982).

The importance of each of these variables, individually, has been established in endurance athletes; yet, little research has examined these variables together in collegiate cross-country runners. This study aimed to assess potential associations between these
individual variables with race performance across a cross-country season. This study also sought to assess the sufficiency of calorie intake, body fat percentage, and perceived social support in collegiate cross-country runners. This study is one of the first to simultaneously assess these variables together, in both male and female cross-country athletes across a single season.

In this study, the cross-country team was relatively inexperienced, with little collegiate racing experience. Both males and females reported an average of approximately one year of collegiate running experience. Average relative VO$_{2\text{peak}}$ attained by males and females in this study was similar to that obtained by collegiate cross-country runners in previous studies (Astorino, 2008; Baumann & Wetter, 2010; Bulbulian, Wilcox, & Darabos, 1986; Scott, Roby, Timothy, & Bunt, 1990). Across the season, males achieved an average relative VO$_{2\text{peak}}$ of $67.9 \pm 3.9$ ml·kg$^{-1}$·min$^{-1}$ (range of 61.8-73.9 ml·kg$^{-1}$·min$^{-1}$). Females averaged $55.7 \pm 4.1$ ml·kg$^{-1}$·min$^{-1}$ (range of 47.7-61.1 ml·kg$^{-1}$·min$^{-1}$). Baumann and Wetter (2010) reported an average relative VO$_{2\text{max}}$ of 71.9 ml·kg$^{-1}$·min$^{-1}$ in NCAA Division I male cross-country runners across an eight to ten-week season. Average relative VO$_{2\text{max}}$ values of 72.1 ml·kg$^{-1}$·min$^{-1}$ and 70.9 ml·kg$^{-1}$·min$^{-1}$ have been reported in male NCAA Division I cross-country and track distance runners during their competitive seasons (Bulbulian et al., 1986; Scott et al., 1990). Baumann et al. (2012) also found an average relative VO$_{2\text{max}}$ of $54.24 \pm 5.88$ ml·kg$^{-1}$·min$^{-1}$ in collegiate cross-country female runners (n=13) prior to their competitive season. Astorino (2008) reported an average relative VO$_{2\text{max}}$ of $69.1 \pm 3.6$ ml·kg$^{-1}$·min$^{-1}$ and $53.7 \pm 2.6$ ml·kg$^{-1}$·min$^{-1}$ in male and female collegiate cross-country runners, respectively.
Ultimately, this suggests that our sample demonstrated similar fitness levels to collegiate cross-country runners studied in previous research.

**Seasonal Changes**

*VO₂peak and Ventilatory Threshold*

No significant changes in VO₂peak were observed in males or females across the pre-season, in-season, or post-season. Despite no significant improvements in VO₂peak, the lack of change from pre-season to post-season indicates that athletes were able to maintain a high level of fitness across the 11-week competitive season. This lack of improvement agrees with previous research, indicating that little change in this variable occurs across a season in collegiate cross-country runners (Astorino, 2008; Baumann & Wetter, 2010).

Baumann and Wetter (2010) found no significant change in VO₂max or ventilatory threshold over an 8- to 10-week season in NCAA Division III male cross-country runners. Additionally, Astorino (2008) observed no significant changes in VO₂max or ventilatory threshold over a competitive season in male or female collegiate runners. Berg et al. (1994) found no significant improvements in VO₂max or ventilatory threshold over one year of training and competition in female collegiate cross-country runners. Ultimately, the findings of this study corroborate previous research, suggesting that in highly trained athletes, there is little room for improvement in physiological variables such as VO₂peak. One possible explanation for this is that athletes may have already been at or near their genetic limit for oxygen uptake (Astorino, 2008). Previous research indicates that VO₂max decreases steadily by approximately 1% each year after age 25 in
normally active men and women (Kenney, Wilmore, & Costill, 2015). This decrease, while influenced by factors such as genetics, activity level, and age, has also been observed in athletes (Kenney et al., 2015). Further, all athletes in this study, with the exception of the incoming freshman, competed in cross-country, indoor track, and outdoor track; thus, athletes who tested at the pre-season time point had concluded the outdoor track season only two weeks prior. These athletes had not had a break from training or competition since the beginning of the previous cross-country season.

**Energy Intake**

This study also found that males and females consistently consumed significantly fewer calories than recommended. Although potential limitations exist due to the self-report nature of the dietary recall, the significant differences between recommended and reported energy intake were noteworthy in this study. Specifically, in the pre-season and in-season, males consumed significantly fewer calories than recommended, with 78% and 70% of males failing to meet recommendations, respectively. On average, males did consume sufficient calories during the post-season. It is also worth noting that these five males were the only ones who completed testing at each time point. Females consumed significantly fewer calories than recommended in the in-season and post-season, with 68% and 66% of females failing to meet recommendations, respectively. This study supports previous research, indicating that collegiate athletes do not consume adequate calories to support performance during a competitive season. Hinton et al. (2004) found that male NCAA Division I athletes consumed fewer calories than recommended. Previous research has also indicated that female collegiate athletes consume insufficient
calories during their competitive seasons (Shriver et al., 2013; Tanaka et al., 1995; Webber et al., 2015).

It is well established that endurance athletes are at risk for eating disorders (Wilmore, 1991) and subclinical eating disorders (Beals & Manore, 1994). Previous research indicates that endurance athletes may put pressure on themselves or perceive pressure from coaches to achieve a certain body weight or composition (Beals & Manore, 1994; Manore, Barr, & Butterfield, 2000). Athletes may deliberately consume fewer calories than recommended to achieve this aim. Hinton et al. (2004) found that 61% of female collegiate athletes assessed reported wanting to lose body weight because they perceived it would enhance performance. More than a quarter of female athletes also reported restricting calorie intake in an effort to achieve this goal (Hinton et al., 2004).

It is well established that sufficient caloric intake is essential for optimal athletic performance (Burke, et al., 2007; Thomas et al., 2016). Thus, related to their nutritional intake, it is reasonable to propose that the athletes in this study may not have been performing under ideal conditions because of their insufficient caloric intake. Although beyond the scope of this study, it is also established that athletes often engage in behavior such as excessive exercise, binging, purging, or an unhealthy preoccupation with weight (Beals & Manore, 1994). When this is considered with our results, this study provides further evidence for the importance of raising awareness around this topic for coaching staff, training staff, and athletes, alike. It is imperative that coaching and training staff understand that their athletes are at risk of disordered eating. Further, all parties should be aware of the risks that habitual caloric insufficiency pose to health and performance. Coaches should be aware of resources they can provide to athletes regarding nutrition and
healthy eating behaviors. As recommended by the National Athletic Training Association, trained professionals should be available to identify these behaviors and provide necessary counseling and support with early screening tools, education, and appropriate referrals (Bonci et al., 2008; McLester, Hardin, & Hoppe, 2014). An appropriate risk management plan, a network of healthcare professionals, and regular education may also be useful in addressing athlete nutrition and eating behavior (Bonci et al., 2008). Evaluating the athlete’s energy intake in the pre-season has merit, as this will allow deficits to be identified and resolved prior to competition. Understanding this risk and taking steps to prevent it in the pre-season may enhance athlete performance during competition.

**Body Composition**

It is also well-established that successful distance runners are characterized by high levels of fat-free mass and low levels of fat-mass (Burke et al., 2007); however, a certain amount of body fat is essential for health (Edler, Wassink, Kahanov, & Eberman, 2014). At each time point across this study, multiple male athletes had body fat percentage levels categorized as risky (<5%) or ultra-lean (5-8%) according to guidelines put forth by the American College of Sports Medicine and other previous research (Edler et al., 2014; Riebe, Ehrman, Liguori, & Magal, 2018). Females in this sample tended to have body fat levels in the healthier ranges, with only one female being categorized as risky (<15%) across this study. No significant changes in fat-mass or fat-free mass in males and females were observed across this study. Fat mass tended to decrease as the season progressed, although weight remained stable, suggesting that lean muscle mass increased as the season progressed. This study supports the findings of previous
research, indicating that the training and competition associated with a cross-country season do not cause significant changes in fat-mass or fat-free mass (Baumann & Wetter, 2010; Berg et al., 2005; Niekamp & Barr, 1995).

Assessing body fat percentage with skinfold measurements, Baumann and Wetter (2010) also found no significant changes in collegiate male cross-country runners across an 8- to 10-week season. Niekamp and Barr (1995) assessed body composition in male cross-country runners over a 12-week season with hydrostatic weighing and observed no significant changes. In collegiate female cross-country runners, Berg et al. (1994) used hydrostatic weighing to assess body fat percentage over a single year of training and competition. They observed a non-significant decrease in body fat percentage over this year (17.4% ± 3.6 to 15.9% ± 3.4) (Berg et al., 1994). Air displacement plethysmography (BOD POD®) was used to assess body composition in the current study. This method produces comparable results to both hydrostatic weighing and skinfold measurements (Bentzur, Kravitz, & Lockner, 2008; McCroy, Gomez, Bernauer, & Mole, 1995; Shim, Cross, Norman, & Hauer, 2014), while having distinct advantages, such as the ease of operation (Riebe et al., 2018). Previous research using the BOD POD® indicates a standard error between one and two percent (McCroy et al., 1995).

Despite the lack of significant changes in fat mass and fat-free mass across the season, it is important to consider the insufficient caloric intake of athletes in conjunction with the low body fat levels in some athletes. A low body fat percentage puts the athlete at risk for many health conditions and may also impair performance (Beals & Manore, 1994; Burke et al., 2007). Thus, this variable should be considered prior to competition by coaching and training staff.
Perceived Social Support

Social support has become increasingly recognized as an important resource for student athletes (Cohen, Underwood, & Gottlieb, 2000). The primary purpose of this aspect of the study was to assess athletes’ perceptions about the availability of social support from others. Specific support groups were not identified; rather, athletes were asked to report their perception of social support from those who they perceive are closest to them. Determining these specific groups was left to the discretion of the athlete. The Perceived Available Support in Sport Questionnaire (Freeman et al., 2011), an instrument that has been validated in similar samples, was used to assess perceived social support in athletes across the season. At this time, no specific score has been identified as a criterion, or minimum standard, for adequate social support in this population. Athletes can score a maximum of 16 on this questionnaire, with higher scores indicating greater levels of social support. Athletes responded to 16 questions, inquiring about four different domains of social support: emotional support, the comfort and security provided them; esteem support, the degree to which others enhanced their competence or self-esteem; informational support, the advice or guidance provided to them; and tangible support, the measurable assistance available to them.

Although no significant differences were found between domains, athletes tended to perceive emotional support as most available to them, followed by esteem support. This finding does support previous research, suggesting that collegiate athletes perceive emotional support as most available to them (Adams, Coffee, & Lavalle, 2015). This may be because emotional support is the easiest to provide to the athlete, as it does not require any special skills or training on the part of the provider. This type of support is more
readily attainable from multiple sources such as friends, professors, and other mentors and does not specifically occur in a sport context.

This has important implications for the athlete’s personal well-being, as adequate emotional support indicates the athlete feels a sense of belonging and feels comforted and cared for (Adams et al., 2015). Additionally, this domain likely has further implications for performance, as it is reasonable to presume that athletes will not perform to their full potential, if they do not feel cared for, secure, or comforted. Athletes’ scores were lower in the tangible and informational support domains. These domains are more specific to sport. They ask the athlete to rate whether they feel they receive adequate advice in competitive situations, regular constructive criticism, tactical advice, advice in poor performance situations, and practical support in travel to competitions. As this was a relatively young group of athletes, they may have simply been unfamiliar with the collegiate sporting and competition system, causing them to perceive lower levels of both tangible and informational support from coaches or training staff.

Females tended to have higher scores than males, though this difference was not statistically significant. Both males and females, on average, scored relatively high on this questionnaire. Thus, in general, athletes perceived that their social support network was adequate. This questionnaire does help to identify individual athletes who may be struggling to perceive adequate social support. Specifically, several individual males scored lower than average on this questionnaire. Although this information may not be statistically significant, it is valuable for coaching and training staff, as they strive to foster a positive environment to enhance athlete quality of life and overall performance.

**Race Performance**
The original intent of this study was to determine a model with the fewest predictors able to significantly and simultaneously predict race performance at each time point. No more than one of these variables was significantly associated with race performance at any given time; thus, statistical analyses were limited to the use of bivariate correlations. Multiple linear regression was not used to determine whether any combination of these variables predicted race performance.

During the pre-season and in-season, no significant associations were seen between any variable (relative VO$_{2\text{peak}}$, ventilatory threshold, fat-free mass, and social support) and race performance in males. During the in-season, relative VO$_{2\text{peak}}$ was significantly associated with race performance in females. In the post-season, fat-free mass was significantly associated with race performance in males, but no significant associations between any variables with race performance were observed in females at this time.

At each time point, the sample size included a relatively homogenous group of trained athletes. This may explain why few significant associations were seen between the selected variables (relative VO$_{2\text{peak}}$, ventilatory threshold, fat-free mass, and social support) with race performance. Previous research has shown that 10-km race time is significantly associated with parameters of aerobic fitness (relative VO$_{2\text{peak}}$ and ventilatory threshold) in males with heterogenous VO$_{2\text{max}}$ values (Morgan, Martin, & Kohrt, 1986). In contrast, Morgan, Baldini, Martin, & Kohrt (1989) found that the same parameters were not significantly associated with 10-km race time when assessing a homogenous sample of runners with nearly identical VO$_{2\text{max}}$ values. The results of the current study are in accord with these latter findings.
Plank et al. (2005) found no significant associations between relative VO$_{2\text{peak}}$ and five-kilometer race time in adolescent cross-country runners. Additionally, Conley and Krahenbuhl (1980) found that, in highly trained male distance runners, 10-km race time was not significantly correlated to VO$_{2\text{max}}$. In contrast, Cole, Woodruff, Horn, and Mahon (2006) found that VO$_{2\text{max}}$ was significantly correlated with best seasonal 5-km race time in adolescent cross-country runners. Baumann et al. (2012) found a significant correlation between VO$_{2\text{max}}$ and 5-km race time in female collegiate cross-country runners. Sell and Ghigiarelli (2017) also found that VO$_{2\text{max}}$ and VO$_2$ at ventilatory threshold were significantly correlated with 5-km race performance time in male and female Division I collegiate cross-country runners. Previous research indicates that other variables, such as running economy (Conley & Krahenbuhl, 1980), lactate threshold (Fernhall, Kohrt, Burkett, & Walters, 1996), and velocity at VO$_{2\text{max}}$ and ventilatory threshold (Morgan et al., 1989) may play a greater role in predicting race performance; thus, these variables may be of interest in future research.

Overall, it has been established that distance runners are characterized by higher levels of fat-free mass and lower levels of fat-mass (Burke et al., 2007). Less research has assessed potential associations between fat-free mass and race performance in collegiate cross-country runners. Dellagran et al. (2015) found that fat-free mass, but not VO$_{2\text{max}}$ was significantly, negatively correlated with 5-km time in adolescent cross-country runners. Bale, Bradbury, and Colley (1986) found that a lower body fat percentage was associated with better times in a 10-km race in national level male distance runners. This study provided mixed results, as a significant association between fat-free mass and race time was only observed at one time point (post-season) and only in males. As multiple
factors influence race performance, these results may suggest that athlete body
composition may not have been as meaningful as other factors in this sample.

Limitations

Athlete participation was a limiting factor in this study. Incoming freshmen were
not able to be recruited until the season was underway; thus, their data was not captured
during the pre-season. In addition, many athletes were unable to complete the study at
each time point, due to illness or injury. Thus, sample size was limited and data for every
athlete was not able to be captured at each time point. Due to the small, homogenous
sample, there were few significant associations between most variables and race
performance. As a result, it was not possible to determine which combination of these
variables predicted race performance with multiple linear regression as was originally
intended.

Race performance was defined by average race time in the most frequently raced
distance of the season for males and females. The real-life design of this study has many
benefits, but it presented some limitations. Races differ in perceived difficulty, elevation,
and terrain; thus, they cannot be compared equally cross a season. Despite this, no
significant differences in time were observed between seasonal races, suggesting that
average athlete race time was representative of their overall seasonal performance.

A multi-pass 24-hour dietary recall was used to simplify the process of obtaining
information about athletes’ energy intake, enhance compliance, and provide an overall
understanding of the athlete’s normal diet. This method also presents potential study
limitations, as it has been established athletes tend to underreport calories consumed when using self-report measures (Gemming, Jiang, Swinburn, Utter, & Mhurchu, 2014).

**Future Research**

Future research could attempt to replicate this study using a more standardized method of race performance. For example, a time trial may have merit for providing an accurate picture of standard athlete performance and changes in performance across a season. This would overcome the inherent difficulties associated with races on varying courses; however, performance in laboratory testing is very dissimilar to actual competition. This study approached the health of the athlete from a comprehensive perspective. Such pre-season evaluations may be useful in other sports, particularly as the athlete transitions to competing at the collegiate level. The transition to higher level competition along with the stress associated with being a student athlete may negatively impact athlete health and performance. Thus, it is valuable to identify deficiencies early and take proactive measures as quickly as possible. Future research could also replicate this study with a more extensive dietary recall method and examine potential interventions to increase caloric intake in cross-country runners.

This study also assessed perceived social support in a general sense and did not ask athletes to identify the primary groups they were receiving social support from. Future research could aim to identify athletes’ perception of their primary source of social support, especially as this was a relatively young group of athletes. This information is valuable for coaching staff, particularly if athletes perceive that they are not receiving sufficient support from the coach. If such deficits are identified, coaching
and training staff are best equipped to meet the athlete’s needs and determine a practical solution to the athlete’s concerns.

Conclusions

This study is one of the first to provide a comprehensive picture of male and female collegiate cross-country runner health across a pre-season, in-season, and post-season. It is one of the first to examine relative aerobic capacity, ventilatory threshold, body composition, energy intake, and perceived social support together in male and female collegiate cross-country runners across this specific time frame. Despite the lack of significant associations between these variables with race performance, this study does have implications for cross-country runners and collegiate athletes.

This study provides evidence that collegiate athletes should be comprehensively evaluated prior to competition. These evaluations have the potential to identify deficiencies in athletes before they begin competition. Specifically, this study highlighted insufficient energy intake in both males and females, and risky body fat levels in some males, two areas that can negatively impact performance and should be addressed promptly in collegiate athletes. Ultimately, the health and performance of the athlete is the coach’s primary concern. Thus, consistently evaluating the athlete through physiological and psychological measures has the potential to enhance overall performance.
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doi:10.1123/ijspp.7.2.170


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new air displacement plethysmograph for measuring human body composition.


APPENDIX A

IRB Approval

TO: Kailyn Sanchez, Department of Physical Education, Health and Recreation

FROM: Ruth A. Galm, Human Protections Administrator

DATE: June 10, 2019

SUBJECT: Physiological Adaptations to Training and Associations with Performance in Division I Cross-Country Athletes (HS-5766)

Based on the amendments provided on June 6, 2019, human subjects protocol HS-5766 entitled “Physiological Adaptations to Training and Associations with Performance in Division I Cross-Country Athletes” has been approved by an expedited review.

A signed and approved copy of your application is being sent in hardcopy.

This student research qualifying for an expedited review is valid for a period of one year. If after initial approval, the research protocol requires minor changes, the Office of Grant and Research Development should be notified of those changes. Any major departure from the original proposal must be reviewed through a Change of Protocol application submitted to the IRB before the protocol may be altered. Please refer to HS-5766 on future correspondence as appropriate as we file everything under this number.

Cc: HS-5766 file
    Dr. Christi Brewer, RPI
    Dr. Katie Taylor, IRB Rep.
    Graduate Office
APPENDIX B

Table 1

*Characteristics of the studies included in the review of VO$_{2\text{max}}$ and race performance*

<table>
<thead>
<tr>
<th>Reference</th>
<th>Population</th>
<th>Study Length</th>
<th>Assessments</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acevedo &amp; Goldfarb (1989)</td>
<td>Trained male runners $(n=7; 22.4 \pm 1.3 \text{ yrs})$</td>
<td>Eight weeks</td>
<td>VO$_{2\text{max}}$</td>
<td>↔VO$_{2\text{max}}$.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lactate at 85-90% of VO$_{2\text{max}}$</td>
<td>↓ Lactate at 85-90% VO$_{2\text{max}}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓10-km race time</td>
</tr>
<tr>
<td>Arrese et al. (2005)</td>
<td>Trained male $(n=25; 23 \pm 4.2 \text{ yrs})$ and female $(n=8; 26.2 \pm 5.4 \text{ yrs})$ runners</td>
<td>Four years</td>
<td>VO$_{2\text{max}}$</td>
<td>↑VO$_{2\text{max}}$ (Class B)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Race performance</td>
<td>↑Race performance (Class B)</td>
</tr>
<tr>
<td>Galbraith et al. (2014)</td>
<td>Trained male runners $(28 \pm 8 \text{ yrs}; n=14)$</td>
<td>One year</td>
<td>VO$_{2\text{max}}$</td>
<td>↑VO$_{2\text{max}}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lactate threshold</td>
<td>↔Lactate threshold</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Running speed</td>
<td>↔Running speed</td>
</tr>
<tr>
<td>Study</td>
<td>Group Description</td>
<td>Duration</td>
<td>Key variable</td>
<td>Findings</td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------------------------</td>
<td>----------------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Saunders et al. (2010)</td>
<td>Trained male runners ($n=34; 32 \pm 7$ yrs)</td>
<td>Seventeen weeks</td>
<td>$VO_{2\text{max}}$</td>
<td>$VO_{2\text{max}}$ was the greatest predictor of peak speed</td>
</tr>
<tr>
<td>Svedenhag &amp; Sjodin (1985)</td>
<td>Trained male long-distance ($n=5; 21.2$ yrs) and middle-distance ($n=5; 22.6$ yrs) runners</td>
<td>One year</td>
<td>$VO_{2\text{max}}$</td>
<td>$↑ VO_{2\text{max}}$</td>
</tr>
<tr>
<td>Baumann et al. (2012)</td>
<td>Collegiate female cross-country runners ($n=13$)</td>
<td>Cross-sectional study</td>
<td>$VO_{2\text{max}}$</td>
<td>$VO_{2\text{max}}$ correlated with 5-km race time and maximal anaerobic capacity</td>
</tr>
<tr>
<td>Baumann &amp; Wetter (2010)</td>
<td>Collegiate male cross-country runners ($n=8$)</td>
<td>Eight to ten-week season</td>
<td>$VO_{2\text{max}}$</td>
<td>$↔ VO_{2\text{max}}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$VO_{2\text{max}}$</td>
<td>$↔$ Ventilatory threshold</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$VO_{2\text{max}}$</td>
<td>$↔$ Onset of Blood Lactate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$VO_{2\text{max}}$</td>
<td>↓ Peak anaerobic power</td>
</tr>
<tr>
<td>Study</td>
<td>Group Description</td>
<td>Study Duration</td>
<td>VO\textsubscript{2max}</td>
<td>Race Time</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------------</td>
<td>----------------</td>
<td>-------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Berg et al. (1995)</td>
<td>Collegiate female cross-country runners (n=7)</td>
<td>One year</td>
<td></td>
<td>5-km race time</td>
</tr>
<tr>
<td>Harber et al. (2005)</td>
<td>Collegiate male cross-country runners (n=5)</td>
<td>Twelve-week</td>
<td>VO\textsubscript{2max}</td>
<td>8-km race time</td>
</tr>
<tr>
<td>Plank et al. (2005)</td>
<td>Male high-school cross-country runners (n=9)</td>
<td>Thirteen-week</td>
<td>VO\textsubscript{2max}, Blood lactate</td>
<td>5-km race time</td>
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Note: ↓significant decrease (p < 0.05); ↑significant increase (p < 0.05); ↔ no significant change (p > 0.05)
Dear Coach Reed,

My name is Kailyn Sanchez and I am a graduate student studying exercise science here at Eastern Washington University. I am seeking to conduct a study assessing factors which contribute to cross-country athlete performance over a competitive season. These factors include maximal aerobic and anaerobic capacity, dietary intake, body composition, and social support. I hope to examine how these factors change over a cross-country season and how these changes are related to performance. This study will also fulfill the requirements for my master’s thesis. Through this study, I hope to provide you with valuable information regarding the performance of your athletes.

With your permission, this study would be conducted over six months and would take place over three testing sessions. I hope to schedule these testing sessions in June, in August, and in November. During each testing session, I will ask athletes to complete a 24-hour dietary recall, a survey asking about their perceived social support, a body composition test, and a maximal treadmill test. I also hope to monitor the training load of the athletes over the cross-country season. With the consent of each athlete, I hope to provide you with their results at the end of each testing session.

With your permission, I wanted to request to attend a team meeting to recruit members of the cross-country team for study participation. During this time, I will read from a script which will describe the study. I will also answer any questions that the athletes have. If they wish to participate, they will have the opportunity to sign an informed consent which will allow them to participate in the study. The study will be open to all athletes who are eligible for sport participation at EWU. I ask that you not request that your athletes participate in this study.

I am happy to provide you with any additional information regarding the study. Please feel free to reach out to me with any questions or concerns. I look forward to speaking more with you in the future.

Thank you,

Kailyn Sanchez
Appendix D

Athlete Recruitment Script

Thank you all for coming. I appreciate you taking the time to meet with me, and I hope to provide you with information about participation in a research study. I will also take the time to answer any questions you may have.

You are being invited to participate in a research study that will examine changes in cross-country athletes over a competitive season. The primary purpose of this study is to investigate changes in your maximal running ability, body composition, calorie intake, and perceived social support over a cross-country season and to see how these relate to your performance. A secondary purpose is to allow me to complete the thesis requirements for my Master of Science degree in exercise science. This study will allow you to learn valuable information about your running ability, dietary intake, body composition and perceived social support. All recorded information will be provided to you at the conclusion of the study. To be eligible for participation, you must be a cross-country athlete who is cleared for NCAA DI sport participation at Eastern Washington University. You must also complete the Physical Activity Readiness Questionnaire (PAR-Q+). The PAR-Q+ is a screening tool that helps determine if it is safe for you to exercise. It will be used with another screening tool from the American College of Sports Medicine to determine if it is safe for you to participate in the study. You will not be eligible to participate if you report any diagnosed cardiovascular, metabolic, or renal disease and/or signs or symptoms that suggest disease on the PAR-Q+.

If you choose to participate, you will be asked to attend three different testing sessions during the cross-country season. Testing will occur in June, August, and November in the Human Performance Laboratory in the Physical Education Health and Recreation Department at Eastern Washington University. During each testing session, you will complete a brief survey with questions about your age, year in school, and years of collegiate running experience. You will complete a 24-hour dietary recall and a survey about the social support you believe is available to you. You will also complete a body composition test and a maximal treadmill test. Each testing session will take between 60-90 minutes. From June to November, you will also continue to record your weekly training volume in the Google Document set up by Coach Reed.

Based on the protocol that we are adhering to, risks of participation are minimal. When completing the electronic surveys, you are free to skip any questions you feel uncomfortable with. If you are uncomfortable during the body composition test or the treadmill test, you will also be free to stop either test at any time. Risks associated with the maximal aerobic treadmill test are minimal; however, as with any form of exercise, there is a risk of musculoskeletal injury, dizziness, fatigue, and in very rare cases, myocardial infarction and sudden death. These risks are very low, given your current training status and health. In addition, you will complete a warm-up and cool-down which will lower risks of dizziness or fatigue.

Your participation in this study is completely voluntary, and you have the right to withdraw at any time. Deciding not to participate or choosing to leave the study after beginning participation will neither result in any penalty nor will it jeopardize your relationship with the coaching staff. It is my intention to present data from this study at conferences and in
publications. For these activities, only group data will be reported. Your individual results will not be shared with anyone; however, you will have access to those results at the end of each testing session. I want to stress that your decision to participate in this study will not affect your standing on the team or with the coach.

I would like to open this time up to answer any questions you may have.
Appendix E

Informed Consent

Physiological Adaptations to Training and Associations with Performance in Division I Cross-Country Athletes

Principle Investigator
Kailyn Sanchez
(541) 979-3041
ksanchez@eagles.ewu.edu

Responsible Project Investigator
Christi Brewer, PhD
(509) 359-4785
cbrewer7@ewu.edu

Purpose & Benefits

You are being invited to participate in a research study that will examine changes in cross-country athletes over a competitive season. The primary purpose of this study is to investigate changes in your maximal running ability, body composition, calorie intake, and perceived social support over a cross-country season and to see how these relate to your performance. A secondary purpose is to complete the thesis requirements for a Master of Science degree in exercise science. This study will allow you to learn valuable information about your maximal aerobic capacity, anaerobic threshold, dietary intake, body composition and perceived social support. All recorded information will be provided to you at the conclusion of the study. To be eligible for participation, you must be a cross-country athlete who is cleared for NCAA DI sport participation at Eastern Washington University. You must also complete the Physical Activity Readiness Questionnaire (PAR-Q+). The PAR-Q+ is a screening tool that helps determine if it is safe for you to exercise. It will be used with another screening tool from the American College of Sports Medicine to determine if it is safe for you to participate in the study. You will not be eligible to participate if you report any diagnosed cardiovascular, metabolic, or renal disease and/or signs or symptoms that suggest disease on the PAR-Q+.

Procedures

If you choose to participate, you will be tested at three different time points over the cross-country season. Testing will occur in June, August, and November in the Human Performance Laboratory in the Physical Education Health and Recreation Department at EWU. During each testing session, you will be asked to complete two electronic surveys. One is a dietary recall survey which will ask you questions about the food and drinks you consumed over the past 24 hours. The second survey will ask you about the social support you perceive is available to you and will ask you to identify your age, year in school, years of collegiate running experience, and whether you belong to the men’s or women’s cross-country team. After this, your height, weight, and body composition (fat mass and fat-free mass) will be measured. Your body composition will be measured via the BOD POD®. For this test, you will be required to wear minimal clothing, similar to the clothing you wear during training and competition, and to sit in a small chamber for 1-2 minutes. Lastly, you will complete an incremental treadmill test to measure your maximal aerobic ability. This test will require you to run on a treadmill as either speed or incline are increased every 2
minutes. During this test, you will be asked to wear headgear, mouthpiece, and nose clip. Each testing session will take ~90 minutes. From June to November, you will also continue to record your weekly training volume as you have already been doing. With your permission, the head coach will give me access to your training log so that I may be able to explain any changes I might see in your fitness or running performance.
Risks, Stress, Discomfort

Based on the protocol that we are adhering to, risks of participation are minimal. The 24-hour dietary recall and perceived social support survey will ask you some personal questions; however, you are free to skip any questions you feel uncomfortable with. There is a slight risk of claustrophobia during the BOD POD® test; however, you are able to end the test if you feel uncomfortable. The equipment required during the treadmill test may cause some discomfort, and the treadmill test itself is physically challenging since we are trying to measure your maximal running ability. The test will last approximately 8-15 minutes; however, you are free to stop the test at any time. Risks associated with the maximal aerobic treadmill test are minimal; however, as with any form of exercise, there is a risk of musculoskeletal injury, dizziness, fatigue, and in very rare cases, heart attack and sudden death. These risks are very low, given your current training status and health. You will complete a warm-up and cool-down to decrease these risks.

Other Information

Your participation in this study is completely voluntary, and you have the right to withdraw at any time. Deciding not to participate or choosing to leave the study after beginning participation will neither result in any penalty nor will it jeopardize your relationship with the coaching or athletic training staff. It is my intention to present data from this study at conferences and in publications. For these activities, only group data will be reported.

If you have any questions about this project, you may contact Kailyn Sanchez at (541) 979-3041 or ksanchez@eagles.ewu.edu or Dr. Christi Brewer at (509) 359-2485 or cbrewer7@ewu.edu. If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator at 509-359-6567 or by email rgalm@ewu.edu.

The study described above has been explained to me, and I voluntarily consent to participate in this research study. I understand that by signing this form I am not waiving my legal rights. I understand that I have had an opportunity to ask any questions regarding my participation in this study. I understand that I will receive a signed copy of this form.

_________________________________________________
Signature of Athlete  Date

_________________________________________________
Signature of PI  Date
# Appendix F

## 2019 PAR-Q+
The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor or a qualified exercise professional before becoming more physically active.

### GENERAL HEALTH QUESTIONS

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Has your doctor ever said that you have a heart condition OR high blood pressure?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2) Do you feel pain in your chest at rest, during your daily activities of living OR when you do physical activity?</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3) Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? PLEASE LIST CONDITIONS HERE:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5) Are you currently taking prescribed medications for a chronic medical condition? PLEASE LIST CONDITIONS AND MEDICATIONS HERE:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past, but it does not limit your current ability to be physically active. PLEASE LIST CONDITIONS HERE:</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7) Has your doctor ever said that you should only do medically supervised physical activity?</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

If you answered NO to all of the questions above, you are cleared for physical activity. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active—start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

### PARTICIPANT DECLARATION

Insert participant’s name and date here.
You have been asked to report everything you ate or drank over the last 24-hours by using an online tool called ASA24. ASA24 stands for the “Automated Self-Administered 24-Hour Dietary Assessment Tool. Depending on the instructions you receive, you will either enter detailed information about all foods, drinks, and supplements you ate or drank from midnight to midnight yesterday, or for the past 24 hours starting from the time you log in. Supplements include vitamins, minerals, herbals, and other dietary supplements. This guide describes the steps you need to follow to complete your 24-hour recall, along with tips and screen shots to help you if you have questions. You can always use the Help button at the bottom of the screen if you can’t find the answers to your questions here.

A few tips:

- It is important that you report all the foods, drinks, and dietary supplements you ate or drank.

- Allow about 30 minutes to complete your recall.

- After 30 minutes of inactivity, you will be automatically logged out of ASA24. But, your information will be saved. Depending on the options selected by the person who asked you to complete a recall, you may or may not be able to log back in to finish.

- If you can’t find the exact item or brand name of what you ate or drank, select the closest match you can find.
• We know that what you eat from one day to the next can be quite different. Please enter only the foods, drinks, and dietary supplements you actually ate or drank, even if they do not reflect your usual diet.

How the ASA24 system flows for 24-Hour Recalls:

Detailed steps in completing ASA24:
Step 1: Report a meal or snack and provide information about it (such as time and location).

➢ If you only had a drink, choose Just a drink.
➢ If you only had a dietary supplement, choose Just a supplement.

Step 2: Search for and select foods, drinks, and dietary supplements you had during the meal or snack.

➢ Select Report a Meal or Snack for each of your other meals and snacks, repeating Steps 1 and 2 until you have reported all your meals and snacks. After you enter the name of an item in the search box, you can select from items in the results or add a recipe. For recipes, first, you will just provide a name for the recipe. Later, in Step 3, you will list all the recipe ingredients.

➢ You will be reminded to check the time gaps between your reported meals and snacks to be sure you did not forget any other meals or snacks. If you did, return to Step 1 to add the forgotten meal or snack and then to Step 2 to add the items you ate or drank.

Step 3: Answer detailed questions about the foods and drinks you had and any recipes you reported. This will include questions about how they were prepared, the amount you ate or drank, and anything added (such as butter on potatoes, or milk on cereal). You will also list the ingredients for any recipes you added. For dietary supplements, you will be asked about dosage.
Step 4: Review what you reported to be sure all foods, drinks, and dietary supplements have been included and that the detailed questions were answered correctly. You can make changes as necessary.

Step 5: Answer questions about items that tend to be forgotten (such as water or dietary supplements).

Step 6: Answer one final question about whether what you ate and drank was less than, more than, or about usual for you.

YOU ARE DONE!
APPENDIX H

The Perceived Available Support in Sport Questionnaire (The PASS-Q)

Below is a list of items referring to the types of help and support you may have available to you as a sportsperson. **Please indicate to what extent you have these types of support available to you.**

<table>
<thead>
<tr>
<th>0 = not at all</th>
<th>1 = slightly</th>
<th>2 = moderately</th>
<th>3 = considerably</th>
<th>4 = extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. provide you with comfort and security</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. reinforce the positives</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. help with travel to training and matches</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. enhance your self-esteem</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. give you constructive criticism</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. help with tasks to leave you free to concentrate</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. give you tactical advice</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. always be there for you</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. instil you with the confidence to deal with pressure</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

If needed, to what extent would someone . . .
<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>10.</td>
<td>do things for you at competitions/matches</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11.</td>
<td>care for you</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>12.</td>
<td>boost your sense of competence</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>13.</td>
<td>give you advice about performing in competitive situations</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14.</td>
<td>show concern for you</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>15.</td>
<td>give you advice when you’re performing poorly</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>16.</td>
<td>help you organise and plan your competitions/matches</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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</table>
Scoring Instructions

Emotional support = (item 1 + item 8 + item 11 + item 14)/4
Esteem support = (item 2 + item 4 + item 9 + item 12)/4
Informational support = (item 5 + item 7 + item 13 + item 15)/4 Tangible support = (item 3 + item 6 + item 10 + item 16)/4
APPENDIX I

Borg RPE Scale

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<th>1-10 Borg Scale of Perceived Exertion</th>
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</tr>
<tr>
<td>9</td>
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<td>10</td>
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# APPENDIX J

## Abbreviated Athlete Training Log

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<th>DATE</th>
<th>Hours of Sleep</th>
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<th>Soreness Level</th>
<th>Stress Level</th>
<th>Daily Comments</th>
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<td></td>
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</tr>
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<table>
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<th>Miles</th>
<th>Time H MM:SS</th>
<th>Avg Pace/Mile</th>
<th>Workout Splits</th>
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<table>
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<td></td>
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<tr>
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VITA

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