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EXAMINATION OF THE RELATIONSHIP BETWEEN PSYCHOMETRIC INVENTORIES THAT ASSESS EATING BEHAVIORS AND ENERGY DEFICIENCY IN MALE ATHLETES

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ABSTRACT

Male athletes, particularly those involved in sports that emphasize leanness, are at risk for developing symptoms of the Male Athlete Triad, which include impaired bone health, suppression of the hypothalamic-pituitary-gonadal (HPG) axis, and energy deficiency. Energy deficiency is a state where the body conserves energy for physiological processes essential to survival due to low energy availability. **Purpose:** The purpose of our study was two-fold: (1) to determine if dietary cognitive restraint (DCR) discriminated between energy deficiency and energy replete status, assessed by serum total triiodothyronine (TT3) and the measured to predicted resting metabolic rate ratio (m/pRMR ratio) in young exercising men, and (2) to determine if DCR was related to disordered eating (DE) behaviors, including Drive for Leanness (DL) and Drive for Muscularity (DM), Perfectionism (P), Body Dissatisfaction (BD), and Drive for Thinness (DT) in young exercising men. **Methods:** Our study was a cross-sectional analysis that assessed measured RMR (mRMR) by using indirect calorimetry and body composition with the Dual-Energy X-Ray Absorptiometry (DXA). DE habits were measured with subscales of the Three Factor Eating Questionnaire (TFEQ), including DCR, subscales of the Eating Disorder Invenotry – 3 (EDI-3), including DT, P, and BD, and separate subscales that included DM and DL in male athletes and recreationally active males (18-33 years). T-tests and Mann-Whitney tests were used to assess differences between groups of high and low DCR. Study participants were classified into a normal DCR (NCR) group (score <13) or high DCR (HCR) group (score ≥13) depending on their TFEQ questionnaire. **Results:** No measures of age (22.28±2.963 vs 22.5±4.815 years, p=0.856), height (180.897±6.8 vs 180.567±6.174 cm, p=0.886), body mass (78.93±10.51 vs 77.668±12.229 kg, p=0.740), percent body fat (% BF) (19.031±2.86 vs

19.542±3.558 %, p=0.631), body mass index (BMI) (24.06±2.50 vs 23.755±3.334 kg/m^2, p=0.745), lean body mass (LBM) (59.53±8.5 vs 59.981±7.799 kg, p=0.874), and fat free mass (FFM) (62.57±8.78 vs 62.928±8.204 kg, p=0.906) among the high DCR (HCR) and normal DCR (NCR) groups were significant (p>0.05). NCR and HCR groups had similar m/pRMR ratios for the Harris-Benedict (0.911±0.076 vs 0.912±0.099, p=0.974), Cunningham$_{1980}$ (0.960±0.080 vs 0.943±0.070, p=0.522) Cunningham$_{1991}$ (1.010±0.084 vs 0.993±0.069, p=0.535), and DXA equations (0.967±0.085 vs 0.931±0.084, p=0.224) and similar TT3 serum concentration levels (114.967±24.04 vs 112.267±12.565, p=0.641). Additionally, there were no significant correlations between TT3 levels and the Harris-Benedict, Cunningham$_{1980}$, Cunningham$_{1991}$, and DXA calculated m/pRMR ratios (p>0.05). The NCR group did not show any significant differences on the P scale when compared with HCR participants (10.03±4.145 vs 11.83±5.149, p=0.246). However, NCR participants had significantly lower BD (4.59±4.997 vs 8.25±5.754, p=0.048), DM (40.41±15.740 vs 52.25±11.717, p=0.024), DT (2.14±2.560 vs 5.42±4.926, p=0.047), and DL (34.52±11.230 vs 43.67±8.370, p=0.015) compared to HCR participants. DCR score was positively correlated with DT (r=0.47, p=0.002), DM (r=0.43, p=.005), and DL (r=0.56, p<0.001). **Conclusion:** Even though DCR score was associated with other DE subscales, detection of energy deficiency in males did not seem to be determined by DCR. Future research must be conducted to clarify if there are associations between eating behaviors measured by DE subscales and energy deficiency in young exercising men.

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Chapter 1

Information

Previous research demonstrates that Drive for Thinness (DT) is a dependable surrogate indicator of energy deficiency in exercising women (De Souza, Hontscharuk, Olmsted, Kerr, & Williams, 2007). Exercising women are also subject to symptoms of the Female Athlete Triad, which can include any combination or at least one of the following: low energy availability (EA) with or without disordered eating (DE), menstrual dysfunction, and low bone mineral density (Nattiv et al., 2007). Energy deficient males have a similar but separate set of symptoms stemming from the Male Athlete Triad, defined as a syndrome that relates three conditions: low EA, impaired bone health, and a suppression of the hypothalamic-pituitary-gonadal (HPG) axis (Nattiv et al., 2021). The Triad and muscularity-oriented eating behavior are most prevalent in sports that emphasize a lean physique, including but not limited to wrestling, rowing, gymnastics, and long-distance running (Nagata et al., 2019). Endurance athletes may fail to meet energy expenditure needs due to unintentional undereating or the experience of DE or an eating disorder (ED).

EDs are characterized by a preoccupation with food, body weight, and shape that leads to behavior such as starvation, fasting, binge eating, purging, and excessive exercise (Bell, 1994). EDs present with high-mortality rates (Smink, Van Hoeken, & Hoek, 2012) and have significant negative consequences to the quality of life of individuals that experience them (Bell, 1994). The prevalence of DE and EDs is lower in male athletes (0-19%) than in female athletes (6-45%) (Bratland-Sanda & Sundgot-Borgen, 2013). There is a higher prevalence of EDs in females than there are in males when studying both athletic populations and non-athletic controls (Baum, 2006). However, when studying the male population, EDs are more prevalent in male athletes than in male controls (Sundgot-Borgen & Torstveit, 2004). Gender-specific risk factors for male athletes include drive for muscularity (DM), steroid use, and homosexuality (Kanayama, Barry, Hudson, & Pope Jr, 2006; Lock, 2009; Russell & Keel, 2002). Sport-specific risk factors for EDs include participation in weight sensitive sports, perfectionistic personality traits, early sport specialization, and overtraining (Smolak, Murnen, & Ruble, 2000; Sundgot-Borgen, 1994). Male athletes are susceptible to such risk factors because of their surrounding sports environment (Currie, 2010).

There are numerous subclinical DE behaviors that are prevalent in both female and male athletes. Dietary cognitive restraint (DCR), which is measured via the Three-Factor Eating Questionnaire (TFEQ) (Cappelleri et al., 2009), is a measure of the chronic effort to achieve or sustain a desired body weight by consciously restricting food intake, and it can be classified as a subclinical ED (Stunkard & Messick, 1985; Vescovi, Scheid, Hontscharuk, & De Souza, 2008). DT is an eating behavior that can be assessed as a component of the Eating Disorder Inventory – 3 (EDI-3) (Garner & Van Strien, 2004). DM, a preoccupation with increasing one's muscle size, has its own separate scale (Garner & Van Strien, 2004; McCreary & Sasse, 2000), a 15-item questionnaire where participants rate themselves on a scale of 1-6; the higher the sum of the scores, the higher the DM (McCreary & Sasse, 2000). Drive for Leanness (DL) is defined as an interest in having low body fat along with toned muscles, and it is measured with an 18-item questionnaire on a 6-point Likert scale (Garner & Van Strien, 2004). Much like DM, the higher the sum of the scores, the higher the DL (Smolak & Murnen, 2008). Perfectionism (P) and Body Dissatisfaction (BD) are psychological constructs that can be measured using the EDI-3 (Garner & Van Strien, 2004). To date, several eating behavior subscales have been linked to surrogate markers of energy deficiency, including the DCR scale, DT scale, and BD in female athletes (De Souza et al., 2007; Gibbs, Williams, Scheid, Toombs, & De Souza, 2011). Bratland-Sanda and Sundgot-Borgen (2013) found that DM is a risk factor for energy deficiency, however it is not compelling and needs to be studied further.

Low EA can have detrimental effects on metabolic and reproductive hormones, including insulin-like growth factor 1 (IGF-1), luteinizing hormone (LH), triiodothyronine (TT3), leptin, insulin, and testosterone. In low EA conditions, the body works to preserve the energy needed for physiological functions which are imperative to survival, and include thermoregulation, cellular maintenance, and locomotion (Wade, Schneider, & Li, 1996). Survival adaptations decrease the resting metabolic rate (RMR) of an individual which decreases the resting metabolic rate ratio (m/pRMR ratio). A ratio lower than 1.0 indicates that the athlete expends less calories at rest than predicted (De Souza et al., 2007). For example, an athlete with a m/pRMR ratio of 0.84 was measured to expend only 84% of their predicted energy expenditure. An athlete with a ratio greater than 1.0 displays a greater measured RMR (mRMR) than their pRMR. A study done on men training at an Army Ranger camp found that when the men were underfed, LH, TT3, IGF-1, leptin, and insulin were decreased (Friedl et al., 2000). However, when the participants were refed, their hormones recovered more readily than hormone recovery has been observed in women (Friedl et al., 2000).

Energy deficiency can lead to reduced levels of testosterone and bone mass in males (Rigotti, Neer, & Jameson, 1986). In women, reproductive dysfunction can be easily detected, as clinical menstrual disturbances are notable, but similar health detriments are not as obvious in men (Bennell, Brukner, & Malcolm, 1996; De Souza & Miller, 1997); however, a Male Athlete Triad does exist. To date, DCR has been found to be negatively associated with mRMR and individuals with high DCR scores are at risk for DE (De Souza et al., 2007). Jurov, Keay, Hadžić, Spudić, and Rauter (2021) found that a majority of the male athletes in his study had lower EA than the EA threshold used for women, suggesting that cut-offs may need to be modified when evaluating male athletes. Measuring EA or energy deficiency may not be feasible in clinical settings; therefore, it is important that easy to use methods are validated as risk assessment tools for energy deficiency in exercising men. Determining if DCR is a surrogate indicator of energy deficiency has the potential to impact how male athletes at risk for energy deficiency and the Triad can be detected.

1.1 Objective

The overall objective of our study was to determine if DCR discriminated between energy repleteness and energy deficiency in young exercising men.

1.2 Specific Aim 1:

To determine if DCR discriminated energy deficiency status, assessed as serum total TT3 and m/pRMR ratio in young exercising men.

The following hypothesis was tested:

Young exercising men that scored ≥13 on the DCR subscale of the TFEQ will have lower TT3 concentrations and lower m/pRMR ratio compared to peers who scored <13 on the DCR subscale.

1.3 Specific Aim 2:

To investigate if DCR was related to other psychometric scales that reflect DE behaviors, including DL and DM, and the following subscales of the EDI-3, including P, BD, and DT, in young exercising men.

The following hypothesis was tested:

Young exercising men that scored ≥13 on the DCR subscale of the TFEQ will have higher scores on the DT, DL, and BD, but not of DM and P.

1.4 Overview of Experimental Design:

Our study was a cross-sectional analysis of male athletes and recreationally active men who were participating in a study on evaluating their anthropometrics, aerobic fitness (VO_2 max), exercise time, RMR and m/pRMR ratio, TT3, and DE behavior to determine if there were relationships between high DCR scores with low m/pRMR ratio and low TT3. The DCR subscale from the TFEQ was investigated as a discriminator of energy deficiency in the active male and male athlete population. Energy status was assessed from the m/pRMR ratio and TT3 concentration. The pRMR was calculated using the equations derived from Harris-Benedict, $Cunningham_{1980}$, $Cunningham_{1991}$, and from body composition, measured with Dual-Energy X-Ray Absorptiometry (DXA-predicted RMR). Eating behaviors were assessed using the TFEQ DCR scale, as well as DM and DL scales, and DT, P, and BD from EDI-3.

1.5 Participants:

Participants were 16 active men and 25 male athletes aged 18-33 years who exercised regularly (at least 150 minutes of purposeful exercise per week), had a body mass index (BMI) between 18.5 and 29.99 kg/m^2, and percent body fat (%BF) below 30%. Men included had peak aerobic capacity (VO_2 max) of at least 44 ml O_2/kg/min as determined with a graded treadmill test, apart from the subjects in the swimmer's study (n=11), from whom VO_2 max was not obtained. Smoking and taking medication that could alter metabolic or reproductive function were exclusion criteria.

1.6 Rationale:

The relationship between DCR and energy deficiency in young exercising males is unclear and serves as the rationale for conducting our work. Few studies have established an association between eating habits and energy deficiency in men. We know that DE is a continuum that can span from dieting and restrictive eating to abnormal eating behaviors, and EDs. There is a higher prevalence of EDs in elite athletes due to their perception of what an ideal body in their sport should look like, because of the idea that being thin will improve performance, or due to societal pressures that a specific eating pattern must be adopted in order to maintain a thin ideal (Sundgot-Borgen & Torstveit, 2010). Risk for EDs is typically higher in elite who participate in sports that emphasize a specific size or shape, high power-to-weight ratio, sports using weight categories, and high-intensity sports. Sport is not the only risk factor, as dieting, coaching, peer pressure, and overtraining are all risk factors that can contribute to DE and lead to energy deficiency (Sundgot-Borgen & Torstveit, 2010). Knowing how to screen high-risk athletes is beneficial to help prevent male athletes from falling victim to symptoms of the Male Athlete Triad.

Studies that have been done indicate that in endurance trained men, low EA is correlated with low testosterone levels, decreased bone density, and RMR (Cupka & Sedliak, 2023). Most research focuses on how low EA effects the vital physiological processes in male athletes. These processes include immune functioning, thermoregulation, and cellular maintenance (Wade et al., 1996). Energetic, reproductive, and bone health (De Souza, Koltun, & Williams, 2019) is more robust in men than in women. This finding is important to understand that more severe energy deficiency is necessary in men to observe effects on energetic, reproductive, or bone health outcomes. More importantly, if prevention is exercised, it could represent an important turning point in helping athletes to maintain a healthy energetic status and avoid complications of the Male Athlete Triad.

Fredericson et al. (2021) found that most studies identified one or more components of the Male Athlete Triad in adolescent and young adult long distance runners, cyclists, and jockeys. Recommended screening questions have also been suggested based off female studies that have been done in the past (De Souza et al., 2014). Fredericson et al. (2021) considers all aspects related to physiology, body composition, and habits that can be affected by the Male Athlete Triad including weight, diet, bone health, and hormone levels experienced by male athletes. By conducting this work, we determined if DCR is an important screening factor for the Male Athlete Triad. Our study was the first to evaluate the relationship between the scales of the TFEQ, EDI-3, DM, and DL with the metabolic hormone TT3 and RMR in exercising men. If DCR is indicative of low m/pRMR ratios, the TFEQ could be a helpful tool in making sure that male athletes are energy replete. Overall, our study may offer further insight on how athletes should be properly fueling themselves to compete without compromising their health. Evidence from our study can also help to form a prevention and treatment plan for those who are at a high risk for energy deficiency and the Male Athlete Triad given their DCR score.

1.7 Expected Findings:

We hypothesized that if young exercising males scored ≥13 on the DCR subscale of the TFEQ, they would have lower TT3 concentration and a lower m/pRMR ratio compared to peers who scored <13. A high score on DCR may be indicative of an athlete's ability to successfully restrain energy intake to control their body weight and physique (De Souza et al., 2007). The more athletes actively engage in restrictive behavior, the more likely an athlete will be at risk for energy deficiency and could experience low concentrations of TT3. Due to the relationships between the subscales of the EDI-3 and DCR (De Souza et al., 2007; Gibbs et al., 2011), we predicted that young exercising men that scored ≥13 on the DCR subscale of the TFEQ would also have higher scores of DT, DL, and BD, but not of DM and P. The higher scores could indicate that DT, DL, and BD can all be related with DCR and DE because DT, DL, and BD are eating behaviors that include restricting caloric intake. However, it is disagreed upon whether DM should be viewed as an ED because building muscle and maintaining leanness is related with eating in a caloric surplus (Cafri, Blevins, & Thompson, 2006; Murray, Rieger, Touyz, & De la Garza García, 2010; Vandereycken, 2011). Additionally, P is subject to the individual and could be influenced based on the feelings of specific athlete of interest.

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Chapter 2

Literature Review

Energetic Factors Affecting the Male Athlete Triad and Psychological Constructs

2.1 Introduction

Energy deficiency is a state where metabolism in the individual is suppressed because there is not sufficient energy from the diet to account for the exercise energy expenditure and other physiological function. If an individual is energy deficient, their body will conserve energy for physiological processes essential to survival and reallocate energy put towards growth and development. Factors that confirm the effects of energy deficiency include decreased TT3 concentrations and resting metabolic rate (RMR). Male athletes, especially those participating in leanness sports, are at risk for developing eating disorders (EDs) or a habit of disordered eating (DE) that can result in energy deficiency (Nattiv et al., 2021). EDs can be evidenced by the Eating Disorder Inventory – 3 (EDI-3) subscale scores (Garner & Van Strien, 2004) that utilize self-report to assess the presence of ED psychopathology and related features (Smith et al., 2017). In males, hormone levels, bone density, and the m/pRMR ratio are some of the only measures that are reliable assessments related to energy deficiency. Additionally, while some male sports praise leanness, many pride muscularity, which may result in the lower prevalence of ED in male sports compared to female sports (Mary Jane De Souza, Koltun, & Williams, 2019;

McCreary & Sasse, 2000). Females tend to fall victim to perfectionism and compulsive exercise behavior due to participation in sports that emphasize leanness and weight loss (Stunkard & Messick, 1985). Low energy availability (EA) is a condition that can occur in the presence of DE or EDs. If an athlete unintentionally expends more energy than they consume relative to their fat free mass (FFM), their inadequate energy intake will not be plentiful enough to account for exercise and physiological functions. First, the individual must use energy for exercise, and if the amount of energy remaining after exercise is low, it is likely that the individual will function poorly. We can study the prevalence of low EA in specific sporting groups for example, in a meta-analysis of studies that compare male and female athletes, it has been shown that 58% of female junior national level soccer players had low EA compared to their male counterparts at just 24% (Cherian, Sainoji, Nagalla, & Yagnambhatt, 2018). In another study, it was found that 31% of female elite distance runners had low EA compared to 25% of males (Heikura et al., 2018). Additionally, young exercising females with a DT score ≥ 7 showed chronic energy deficiency symptoms, including an m/pRMR ratio below 90%, significantly lower TT3 levels, and significantly higher ghrelin levels than females who scored ≤ 6 (M. J. De Souza, Hontscharuk, Olmsted, Kerr, & Williams, 2007). In a cohort study aimed to examine male clinical norms from ED measures and to evaluate differences found between sexes in overall ED pathology, men were found to have lower scores on all subscales including Drive for Thinness (DT), Body Dissatisfaction (BD), and Perfectionism (P) (Smith et al., 2017). Further, the clinical male scores on the EDI-3 were higher than non-clinical male scores, indicating that EDI-3 scores could be related to the severity of the ED that the male patient was admitted for (Smith et al., 2017).

Drive for Leanness (DL) has been shown to be significantly correlated with both DT and Drive for Muscularity (DM) in male athletes. DL has also been shown to be a good comparison between males and females, as it was found that gender did not present any differences in the DL measure. Women, however, tended to demonstrate higher DT and men displayed higher DM (Mary Jane De Souza et al., 2019). Factors that seemed to influence a higher muscularity-oriented eating behavior in exercising males includes exercising to gain weight, self-perception of being underweight, lower BMI z-score, and participation in weightlifting (Nagata et al., 2019). Males are observed to have more severe ED pathology in the sports that favor leanness, for example, judo, cycling, wrestling, and long-distance running. A cross-sectional study on male judoists and cyclists set out to test if body-weight specific sports increased the risk of presenting with subclinical EDs. It sampled 12 judoists (19.5±0.5 years), 15 cyclists (21.2±2.8 years), and 17 non-competitors used as controls (21.8±1.8 years) (Filaire, Rouveix, Pannafieux, & Ferrand, 2007). Filaire et al. (2007) found that both groups of athletes differed significantly from the controls with their EAT-26, dieting, and bulimia scores. The main method of weight loss was increasing exercise and when asked, 60% of the participants reported using some method of weight loss. The athletes also displayed greater negative feelings towards their appearance and about their body weight (Filaire et al., 2007). Male athletics that encourage a lean figure teach athletes to restrict and adapt eating habits that won't only affect their psyche, but also the hormones necessary for homeostasis.

Energetic status, reproductive status, and bone health are more resilient to low EA in men than in women, evidenced by hypothalamic pituitary gonadal (HPG) axis disruption recovering more quickly in men than in women (Mary Jane De Souza et al., 2019). Despite the male metabolic resilience, exercising males are still impacted by low EA and energy deficiency. Studies have found that endurance sport male athletes had reduced luteinizing hormone (LH) levels, which indicated a report of hypogonadotropic hypogonadism, a condition where little to no sex hormones are being produced (Friedl et al., 2000). Males experiencing hormone deficiency were also reported to have lower testosterone, decreased semen quality, and symptoms of infertility (M. De Souza, Arce, Pescatello, Scherzer, & Luciano, 1994). Exercising men are at a lower risk for EDs than exercising women, but have similar adaptations compared to their female counterparts. Testosterone is sensitive to psychological stress and a disbalance of energy but promptly recovers when energy levels resurge (Friedl et al., 2000).

2.2 The Male Athlete Triad in Male Athletes

The Male Athlete Triad, like the commonly studied Female Athlete Triad, is a syndrome relating three conditions which include energy deficiency as a result of low EA, impaired bone health, and suppression of the HPG axis (Nattiv et al., 2021). There is not a quantitative definition of energy deficiency. However, low EA can be defined as having low energy available from diet for daily activities and physiological function, after accounting for the energy cost of exercise. Low EA is calculated as energy intake minus exercise energy expenditure, relative to fat-free mass ((EI-EEE)/FFM)) (kcal/kg fat free mass [FFM]/day). Lieberman, De Souza, Wagstaff, and Williams (2018) found that the probability of predicting a menstrual disturbance in female athletes increased by over 50% if the athletes displayed an EA lower than 30 kcal/kg FFM/day. An EA value cut-off must be higher for men, as men have more resilient energetic status, reproductive status, and bone health. Men also exhibit lower DT scores, which may indicate that male athletes are less likely to engage in restrictive behavior to be thin. However, the 30 kcal/kg FFM/day serves as a baseline that is known to show elicit symptoms of the Female Athlete Triad (Mary Jane De Souza et al., 2019).

Even though low EA has been investigated more in female athletes than in male athletes, there is evidence suggesting that men require a more severe deficit to experience metabolic complications. In the Friedl et al. (2000) Army Ranger study, two groups were tested, both experiencing a multi-stress environment of extreme exercise and diet; the first one (n=49) had a 1200 kcal/day deficit and the second group (n=48) had a 1000 kcal/day deficit over an eight-week period which included four cycles of restricted eating and refeeding. All participants were young, lean, and healthy males who endured the same amount of endurance and leadership training in an Army Ranger course. With the intervention, the group with the greatest deficit achieved minimum body fat (<4%), below normal TT3 levels (78±20 ng/dL), testosterone reached castrate levels (4.5±3.9 nmol/L) and insulin-like growth factor 1 (IGF-1) halved (75±25 μg/L). Cholesterol rose from 158±31 mg/dL to 217±39 mg/dL. After the first week of refeeding, triiodothyronine (TT3) and IGF-1 recovered promptly but began to decline once food was restricted again. Group two saw a similar pattern in week five. Testosterone declined well below a healthy level for men but promptly recovered in week five for both groups with refeeding. The second group stayed above the clinical levels of hypothyroidism and hypercholesterolemia. Both groups had suppressed LH, indicating that there was a common threshold for gonadal hormone suppression between the groups (Friedl et al., 2000).

From Friedl et al. (2000), it was observed that low TT3, testosterone, IGF-1, and LH were markers of acute energy deficits in the presence of stressful environments. Elevated cholesterol and cortisol alluded to more chronic statuses of energy deficiency because of their correspondence to diminishing fat stores (Friedl et al., 2000). Although menstruation cannot be an indicator of the Triad in male athletes like it was for female athletes, we relied on the endocrine system to be consistent with low EA. When exercising men were in a negative energy balance, reduced hormone concentrations coincided with the lower energy intake, leading to lower levels of fat-stores (Friedl et al., 2000).

2.3 Objective and Rationale for this Review

There are many factors that can contribute to energy deficiency in male athletes including DL, DM, DT, P, and dietary cognitive restraint (DCR), which could indicate that male athletes are experiencing an ED or DE. An ED is a clinically diagnosable disease. Some of the commonly studied disorders include Anorexia Athletica (AA), Anorexia Nervosa (AN), Bulimia Nervosa (BN), and EDs Not Otherwise Specified (EDNOS). Some of the psychopathologic symptoms of EDs include 1) a disturbance of delusional proportions in the body image 2) a disturbance in the accuracy of the perception or cognitive interpretation of stimuli arising from the body, and 3) a paralyzing sense of ineffectiveness and helplessness (Stunkard & Messick, 1985).

Athletes typically display more symptoms and are diagnosed with EDs more often than the general population, especially those that participate in leanness sports. Overall, the prevalence of male athletes that are at risk for an ED is 9% and those clinically diagnosed is 8%. Comparing this statistic with their female counterparts, 21% of women are at risk for an ED and 20% of women are diagnosed (Sundgot-Borgen & Torstveit, 2004), illustrating the difference between male and female eating pathology. This difference highlights the importance of establishing a method where male EDs can be detected more frequently if necessary.

Different than ED, DEs are subclinical and common psychiatric pathologies (Karrer et al., 2020). DE can be influenced by sport type, as weight-sensitive sports tend to have athletes that have a higher DE prevalence (Rice et al., 2016). DE has also been found to be negatively associated with positive perfectionism, which is an achievement-oriented aspect of perfectionism with the goal of obtaining high-level goals for positive consequences. Negative perfectionism is the need to achieve the same high-level goals to avoid negative consequences, however, no significant association was found with DE in male athletes (Haase, Prapavessis, & Owens, 2002).

The objective of this review was to summarize our current knowledge of low EA, energy deficiency, energetic factors, and DCR in exercising males and females. We also examined the known relationships of DCR with EDI-3, TFEQ, DM, and DL scales. The gaps in the literature will be discussed to explain where future investigation should be focused in this area of study on male athletes and exercising men.

2.4 Low Energy Availability, Energy Deficiency, and Reproductive Considerations in Male Athletes

Low EA is defined as a condition where energy intake is too low to account for exercise energy expenditure and normal physiological function (Loucks & Heath, 1994). If athletes or recreationally active individuals are at a chronic state of low EA, the athlete may experience energy deficiency. Many metabolic and reproductive outcomes may occur because of energy deficiency, such as reduced TT3, IGF-1, and testosterone (Friedl et al., 2000). A suppressed resting metabolic rate (RMR) may indicate energy deficiency caused by low EA, as the body must ration the energy to the key factors that are essential to survival: locomotion, cell maintenance, and thermoregulation (Wade, Schneider, & Li, 1996). When energy reallocation occurs, the reproductive axis is disturbed, and hormones like testosterone and LH are altered to accommodate for change. There is also an associated decrease in hormone levels such as TT3 to accommodate for less available energy from the diet (M. J. De Souza et al., 2007).

Because energy deficient individuals have a reduced RMR, energy deficiency can be measured by the m/pRMR ratio. RMR is a measure of total resting daily energy expenditure and includes all energy requirements necessary to survive and maintain homeostasis, without accounting for daily activities and digestion (Flack, Siders, Johnson, & Roemmich, 2016). To calculate the m/pRMR ratio, the subject has their actual RMR measured (mRMR), typically with indirect calorimetry, and it is necessary to calculate the predicted RMR (pRMR) from predictive equations, such as the Harris-Benedict equation (Harris & Benedict, 1918), the Cunningham equations (Cunningham, 1980, 1991), or the DXA-predicted RMR (Elia, 1992; Hayes et al., 2002; K. Koehler et al., 2016). The m/pRMR ratio is calculated by from dividing the mRMR by the pRMR (m/pRMR ratio). In women, having a Harris-Benedict m/pRMR ratio below 0.9 is suggested to indicate energy deficiency, whereas m/pRMR ratio above 0.9 would be classified as energy replete. The exact cut-off may vary according to what predictive equation is used (Strock, Koltun, Mallinson, Williams, & De Souza, 2020; Strock, Koltun, Southmayd, Williams, & De Souza, 2020).

TT3 is a thyroid hormone responsible for controlling physiological functions that include growth and development, metabolism, body temperature, and heart rate (Silverthorn, 2010). Karsten Koehler et al. (2016) administered a cross-over design study, with six active and healthy males aged 18-30 who underwent two 4-day conditions of low EA (15 kcal/kg FFM/day) and two 4-day conditions of energy balanced, or control days (40 kcal/kg FFM/day). Participants expended 15 kcal/kg while performing exercise under supervision during one low EA and one control condition. In the remaining 4-day conditions, the participants performed no exercise. The objective of the study was to determine the impact of a controlled energy reduction stage on metabolic hormones (leptin, ghrelin, insulin, TT3, testosterone, and IGF-1) and if those effects differ if the participant is in an energy deficit with or without exercise. Regardless of exercise level, males that were in a low EA condition had decreased leptin and insulin levels, while ghrelin, TT3, testosterone, and IGF-1 appeared to be unaffected (Karsten Koehler et al., 2016). Leptin is an appetite regulator and insulin is released as a response to increased levels of blood glucose, with the purpose of transporting glucose to the cells and inducing anabolism, including glycogenesis and lipogenesis. Leptin has a direct link to the suppression of the reproductive, growth hormone/IGF-1, and thyroid axes, and it has been suggested that it serves as an acute metabolic signal of starvation and energy conservation. Leptin's role in reproduction, along with IGF-1 axes is essential to homeostasis (Karsten Koehler et al., 2016).

Testosterone is an endogenous primary male sex hormone that stimulates the development of male reproductive tissues and maintains male characteristics. It also stimulates muscle mass growth and reduces body fat (R. I. Wood & Stanton, 2012). Testosterone is an important hormone in development, and the effects of low EA can have a negative effect on male athletes. In a cross-sectional study, two groups, participants of endurance exercise training programs for ≥ 5 years (n=11) and untrained and sedentary individuals (n=11), had their resting reproductive hormonal profiles compared. In endurance-trained athletes, free testosterone (17.2±1.4 pg/ml) and total mean testosterone (4.99±0.46 ng/ml) were lower when compared with untrained males

(23.6±0.6 pg/ml and 7.25±0.67 ng/ml respectively) (Hackney, Sinning, & Bruot, 1988). The study also found that cortisol was not a causative factor for lowering testosterone. Hackney et al. (1988) suggests that it is not the stress of exercise but the chronic endurance training itself that reduces testosterone and could be inhibiting testicular function, supporting the idea that chronic exercise is what causes hormonal disturbances, not cortisol.

2.5 Overview of Disordered Eating Subscales in Male Athletes

Athletes with subclinical EDs may show evidence of some common psychological traits associated with clinical EDs such as high achievement orientation, obsessive-compulsive tendencies, and perfectionism (Sundgot-Borgen & Torstveit, 2004). In addition to psychological traits, there are scales that have been developed to identify abnormal eating patterns such as DE and EDs. As mentioned before, the psychological factors include DT, DL, DM, P, BD, and DCR (Garner & Van Strien, 2004).

DT is a measurement of DE due to body weight, shape, and image concern. It is assessed on a scale derived from the EDI-3 (Garner & Van Strien, 2004). DM has its own scale that assesses the preoccupation with increasing one's muscle size (Garner & Van Strien, 2004). A higher score indicates a higher DM (McCreary & Sasse, 2000). DL is defined as an interest in having low body fat along with toned muscles, and similarly to DM, higher scores reflect higher DL (Garner & Van Strien, 2004; Smolak & Murnen, 2008). P and BD are additional eating behaviors that can be measured using the EDI-3 (Garner & Van Strien, 2004). Other self-reported measures of eating behaviors include DCR which is measured via the TFEQ (Cappelleri et al., 2009). DCR is a measure of the chronic effort to achieve or sustain a desired body weight by consciously restricting food intake, and it can be classified as a subclinical ED (Garner & Van Strien, 2004; Vescovi, Scheid, Hontscharuk, & De Souza, 2008).

2.6 Overview of Dietary Cognitive Restraint in Male Athletes

The TFEQ measures three domains of eating behaviors including restraint, disinhibition, and hunger (Cappelleri et al., 2009). Restraint is a term used to describe the concern of an individual over their weight and the strategies adapted to maintain a specific body weight. An individual could accomplish this by restricting food by eating smaller portions, avoiding food groups, or not eating to satiation. Disinhibition refers to the tendency to overeat because an individual is unable to resist hunger cues, eat in response to stress, or feel the need to eat because it makes them feel satisfaction. Hunger measures the extent to which hunger feelings are perceived and the extent to which it can evoke food intake (Bryant, Rehman, Pepper, & Walters, 2019; Stunkard & Messick, 1985).

The studies in **Table 1** assess the components of the TFEQ and DCR (restraint, disinhibition, and hunger) in athletic populations and populations focused on losing weight. After reviewing the studies, four determined a cut-off score for the subscales on the TFEQ (Jurov, Keay, Hadžić, Spudić, & Rauter, 2021; Vescovi et al., 2008; Westenhoefer, 1991; K. L. Wood et al., 2021). Garner, Olmstead, and Polivy (1983) determined that a score of >20 could indicate a possible risk for EDs (Garner et al., 1983). Filaire et al. (2007) assessed male judoists, cyclists, and controls with an eating attitudes test (EAT-26) and found that 67% of the male cyclists and 25% of the judoists were not satisfied with their weight. Despite this dissatisfaction, the athletes did not score differently from the controls on the P scale (Filaire et al., 2007). From the judoists and cyclists, we can learn that although perfectionism is a component of DE patterns (Davis, 1997) the athletes displayed that perfectionism can't be indicative of EDs. The EAT-26 measures P, body-esteem, and mood states, so although it is different from the TFEQ, there are overlaps in subscales. Vescovi et al. (2008) determined high-DCR to be ≥9 and normal-DCR to be <9 in physically active premenopausal women and found that the high-DCR group showed lower total body and lumbar spine BMD and more frequent oligo-amenorrhea. The participants that had DCR scores of >13 were also observed to have a lower m/pRMR ratio. Vescovi et al. (2008) showed that high DCR can indicate bone health pathology, but as DCR increases, symptoms of energy conservation arise.

Westenhoefer (1991) used the TFEQ to evaluate overweight participants and found that moderately high DCR was classified as a score of 10-13. K. L. Wood et al. (2021) assessed a sample of cross-country runners in Southern California and determined that a score of ≥11 was indicative of elevated DCR. Additionally, in a study done by Jurov et al. (2021), 75% of the male endurance athletes reported critical DCR (≥13). From these three studies, we can determine that there is a range where high-DCR may fall on the TFEQ. However, Jurov et al. (2021) suggests that to see clearer differences in blood samples and psychological scores, male athletes must experience more extreme dieting. More extreme measures could include a higher cut-off for DCR and feeding participants less than the threshold set for female athlete EA (30 kcal/kg FFM/day). Male athlete metabolic resilience plays a key role in energy conservation, and including more extreme measures could give researchers a more accurate threshold for minimum energy intake and psychological questionnaires (Friedl et al., 2000).

In a study done by Sesbreno et al. (2021) the mean score of DCR was used to split participants into low and high groups to evaluate energy intake. The study found that the majority of elite male volleyball athletes were not consuming enough to meet the demands of their body, and athletes with a high DCR score are at a higher risk for injury associated with low EA (Sesbreno et al., 2021). The study indicates how DCR can heighten risk of injury or DE, especially if an athlete does not have an adequate energy intake. Krempien and Barr (2012) assessed Canadian athletes with a spinal cord injury (SCI) with the TFEQ and found that the male athletes scored higher on DCR than the able-bodied population, but the female athletes scored similarly to the able-bodied females. This finding illustrates the gender differences in DCR in injured and able-bodied populations, as the injured male population scored very closely to the injured and able-bodied females, a much higher score than the able-bodied population of men (Krempien & Barr, 2012). Other literature included in this review evaluated the relationships between eating pathology, DCR and gender, and sport. Karrer et al. (2020) found that sports that encourage higher levels of competition and leaner body types was more likely to result in a higher likelihood of DE. The prevalence of EDs in male athletes was 32.5%, higher than the general population. From the Karrer et al. (2020) study, we can gather that risk factors can be very impactful and crucial to understanding DE and EDs in male athletes.

Male athletes engage in DCR to intentionally achieve a certain weight or achieve a certain leanness for their sports. Female athletes tend to have higher DCR scores, but extreme DCR is still observed in male athletes, especially those that participate in leanness sports including but not limited to running, long jump, high jump, ski jumping, gymnastics, wrestling, judo, karate, diving, or bodybuilding (Sundgot-Borgen & Torstveit, 2010). Additionally, EDs and DE is more prevalent in exercising males compared to sedentary males due to pressure from sport, coaches, or social environment (Karrer et al., 2020).

Table 1: Studies assessing DCR, EAT-26, and EDI-3 Questionnaire Measures

Study	Participants (description)	Purpose and methods	DE Subscales Cut-off Scores	Findings
Bryant et al., 2019	76 papers total Adult samples of 18+ years Studies published from 2013-2018	Purpose: Explore roles of the TFEQ Restraint and Disinhibition in relation to adult obesity and eating disturbance ED. Methods: Literature search was performed in PsycINFO, Science Direct, and PubMed.	Restraint can be related to lower body weight and diet OR obesity, poor diet, & overeating. Disinhibition is related to increasing energy intake and susceptibility to disturbed eating.	TFEQ scores: Women > men scores Older people > younger people. Restraint can be related to lower body weight and diet OR obesity, poor diet, & overeating. Disinhibition is related to increasing energy intake and susceptibility to disturbed eating.
Filaire et al., 2007	N=12 judoists aged 19.5±0.5. N=15 cyclists aged 21.2±2.8. N=17 non-competitive students aged 21.8±1.8.	Purpose: Determine if male athletes who feel pressured to maintain a specific body weight present an elevated risk of subclinical ED. Methods: EAT-26 test, Multidimensional Perfectionism Scale, the Body Esteem Scale, &	EAT-26 score ≥ 20 identified individuals at risk for an ED	Scores on EAT, Dieting, and Bulimia differed between male athletes and the control group. 60% of athletes used weight loss methods. Increasing exercise was the most common weight-loss method.

		the Profile of Mood States.		
Jurov et al., 2021	Cross-sectional N=18 male participants; 18-35 years, 19-25 kg/m^2 BMI, 5-20% body fat, 55-64.9 ml/kg/min VO2 max (well-trained), no acute disease or injury, stable body mass/no diet, no alcohol or drug use.	Purpose: Measure energy availability in healthy male endurance athletes in pre-season. Methods: Participants were given the TFEQ and well-being questionnaires.	Subgroups: EA ≥ 30 kcal/kg FFM/day EA < 30 kcal/kg FFM/day Critical cognitive restraint score ≥ 13	EA had significant negative correlation with EEE. Energy intake had significant positive correlation with DCR; negative correlation with mRMR and p/mRMR ratio.
Karrer et al., 2020	N=80 studies N=14 controlled N=47 uncontrolled N=1 interventional N=18 studies and reviews	Purpose: Provide a scoping review of ED and DE in male athletes. Methods: Conducted a comprehensive systematic literature search for DE and ED in male athletes.	Higher level of competition = higher DE Weight sensitive sports = higher DE	ED prevalence in male athletes is 32.5%, higher than the general population. Most frequent associated factor was weight-sensitive sports. Male athletes showed less BMD than controls.
Krempien et al., 2012	N= 24 men N= 8 women Canadian athletes with a SCI, members of the	Purpose: Assess the factors influencing the energy intake of those with a SCI including	≥ 11.5=high restraint < 11.5=low restraint Typical scorers for the able-bodied groups are	SCI male athletes DCR score (11.1±5.0) > able-bodied adult males DCR score (6.7±3.7).

	national team training for ≥12 hr/wk ≥19 years old (N= 20 wheelchair rugby, N= 7 wheelchair basketball, N= 3 para-alpine skiing, N= 2 wheelchair athletics)	food related attitudes and behaviors. Methods: Cross-sectional design measured eating attitudes with the TFEQ along with 6 days of self-reported dietary intake and body measurements.	between 5-7 (restraint and hunger score).	SCI female athletes scored similarly to the female population 11.0±5.4 (6.4±4.8 for vegetarians). Together: Mean DCR=10.8±4.7, Disinhibition=2.8±1.8, Hunger=3.1±2.2. Hunger and disinhibition scores: SCI group < able-bodied population.
Sesbreno et al., 2021	N= 22 elite male volleyball athletes ≥ 18 years Part of the senior national team or NextGen program with the potential to qualify for the men's national team. Athletes were training 20 hours a week.	Purpose: Compare dietary intake of male volleyball athletes within recommendations for sport and health, and to examine the associate of physique traits and knee health on eating behaviors. Methods: Cross-sectional study measured anthropometry, dual-	DCR eating mean score: 30.6 ± 17.1	Most players did not consume enough energy using the sports health guidelines. Primary eating behavior was DCR. Players are at risk of impaired ability to adapt to and recover from training during peak competition.

		energy X-ray absorptiometry, and resting metabolic rate testing, 4-day dietary intake and hematological analysis, TFEQ scores, and patellar tendon questionnaire scores.		
Vescovi et al., 2008	N=84 physically active (500±30 min/ week) premenopausal women: N=38; DCR score ≥ 9 (high). N=46; DCR score < 9 (normal).	Purpose: Compare BMD and BMC, menstrual and metabolic status between physically active women with high DCR, normal DCR, and across quartiles of DCR scores. Methods: Observational study, TFEQ classified DCR groups, DXA scans assessed BMD, menstrual status was self-reported, RMR was measured by indirect calorimetry canopy method, blood samples	First quartile: DCR = 0-4 Second quartile: DCR = 5-8 Third quartile: DCR = 9-12 Fourth quartile: DCR = ≥ 13	Body mass and %BF were similar between the groups. High-DCR group had lower total body and lumbar spine BMD. Oligo-amenorrhea was more prevalent in the high-DCR group and increased prevalence across the quartiles. The RMR and m/pRMR ratio was lower in the fourth quartile (DCR ≥ to 13).

		were taken to assess hormones.		
Westenhoefer, 1991	N=54,525 voluntary participants in a weight reduction training program; majority were overweight, and the program ran for 12 months.	Purpose: Determine the relationships between items that measure DCR and the disinhibition scale. Methods: Participants were given the TFEQ, documented major problems in their eating, and any means of weight control.	Low disinhibition= <5 High disinhibition= >12 High restraint = >0 on every restraint item Moderately high restraint = 10-13 Low restraint = no score	DCR is not homologous when it comes to disinhibition.
Wood et al., 2021	N= 40 Cross-country runners in Southern California 14-17 years old ≥25 miles ran per week. Event was ≥1 mile. None were diagnosed with EDs	Purpose: Investigate associations between DCR, energy, macronutrient and food group intake, menstrual function, and BMD in female adolescent endurance runners. Methods: A cross-sectional study; participants completed a TFEQ along with other measures of energetic factors.	Elevated DCR ≥11 on a scale from 0-21.	Lower energy consumption (kcal/kg/day) (37.5 ± 8.6 vs. 44.0 ± 9.6) and lower lumbar spine BMD Z-scores (adjusting for BMI) (− 0.78 ± 0.19 vs. − 0.22 ± 0.12) were observed in runners with high DCR compared to normal. DCR impacts dietary intake & lumbar spine density.

2.7 Conclusions

Overall, the table summarizes studies that were the foundation to build upon in our study. Elevated DCR scores were found in both male and female endurance athletes, physically active males, and physically active females. All scores were >10, and Jurov, Keay, Hadžić, Spudić, and Rauter (2021) established a DCR score of ≥13 as a cutoff in his study, which served as the cutoff score in our study. We know that women tend to have higher DCR scores than men (Bryant, Rehman, Pepper, & Walters, 2019), however, the male athlete population is 32.5% more at risk for experiencing ED (Karrer et al., 2020). Furthermore, in the Krempien and Barr (2012) study, it was shown that athletes, even those with a SCI, were more prone to higher scores on three dimensions on the TFEQ that impact DCR: hunger, restraint, and disinhibition. While the females scored relatively similar to their able-bodied counterparts, the SCI men scored significantly higher than able-bodied men and very similar to the female population, implying able-bodied men are not as likely to score as high as females (Krempien & Barr, 2012). Additionally, the suggestion that men may require a more intense energy regimen to yield significant results highlights the necessity for further research on male athletes to evaluate their metabolic responses (Jurov et al., 2021).

It is still unclear if there are relationships between subscales that evaluate DE and energy deficiency in male athletes. We know that competition level and weight-sensitive sports showed higher levels of athletes with DE. Furthermore, Army Rangers who were under significant physical and psychological stress have shown decreases in important metabolic and reproductive hormones as well as energy. To our knowledge no studies have been done to associate DCR with low EA and the effects of energy deficiency in active male athletes. However, studies have found that men with higher DT and BD (score >10) were more likely to be at risk for EDs (Martinsen & Sundgot-Borgen, 2013). DCR scores, TT3 levels, and the m/pRMR ratio are key measurements that will aid in determining if DCR impacts the Male Athlete Triad and energy deficiency in male athlete subjects. Future research should attempt to measure these factors along with DM, DL, P, and BD scales. Finding relationships between DE scales and their ability to discriminate energy deficient male athletes from energy replete male athletes will be helpful in screening procedures in the future.

2.8 References:

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Chapter 3

Methods

3.1 Study design

The present study reports preliminary findings from a data set derived from three studies: a cross-sectional study investigating energy status, metabolism, and stress in collegiate swimmers (n=11); a larger ongoing cross-sectional study investigating metabolism, reproductive function, stress, and bone health in young exercising men (n=22, 16 recreationally active men and 6 athletes); and an ongoing longitudinal study investigating metabolism, reproductive function, stress, and bone health in collegiate athletes across a competitive season, of which only the baseline measurement from male athletes has been used (n=8). The latter of the eight, five collegiate athletes were also enrolled in the cross-sectional study in active men; therefore, the final total sample size (n) was of 41 active young men. Participants from all three studies completed measurements of RMR, body composition with a DXA device, and serum total TT3, to investigate the relationship between the measured-to-predicted resting metabolic rate ratio (m/pRMR ratio) and TT3.

3.2 Participants

Participants included 11 male swimmers, 14 male athletes, and 16 recreationally active men aged 18-33 years who habitually exercised (at least 150 minutes of purposeful exercise per week) and had body mass index (BMI) between 18.5 and 29.99 kg/m^2, and percent body fat (%BF) below 30%. Men included had peak aerobic capacity (VO_2 max) of at least 44 ml O_2/kg/min as determined with a graded treadmill test, except for the subjects in the swimmer's study (n=11), from whom VO_2 max was not obtained. Those that smoked or were taking medication that could alter metabolic or reproductive function were excluded.

3.3 Anthropometrics and body composition

A physician's scale was used to assess body mass to the nearest 0.1 kg, and a stadiometer was used to assess subject height to the nearest 0.1 cm. A Dual-Energy X-Ray Absorptiometry (DXA) device (Hologic QDR Horizon W, X-Ray Bone Densitometer, Hologic, Bedford, MA) was used to assess body composition, i.e. total fat mass, lean body mass (LBM), fat-free mass (FFM), and %BF, performed by an International Society of Clinical Densitometry-certified technician.

3.4 Peak aerobic capacity (VO_2 max)

All subjects, expect for the participants of the study on swimmers, performed a graded treadmill test to exhaustion for a measurement of VO_{2Max}. After a 2-min walking and jogging warm-up period, subjects were allowed to choose a speed to run at 0.0% grade. For the first six minutes of the test, grade was increased 2% every two minutes, followed by a 1% increase in grade every minute until volitional exhaustion was achieved. VO_2 and CO_2 were measured using a metabolic cart (SensorMedics Vmax Series; CareFusion,Yorba Linda, CA). At least two of the following criteria were achieved for the test to be considered valid, including a max heart rate, a

RPE of at least 18, an RER >1.15, and a plateau in VO_2 uptake despite an increase in workload (Barker, Williams, Jones, & Armstrong, 2011).

3.5 Exercise Time

To validate that participants were active, a minimum of 150 minutes of purposeful exercise weekly, participants were asked to record type, duration, and average hear rate for every exercise session practiced throughout seven consecutive days on exercise logs. Participants were asked to wear activity monitoring devices to record exercise sessions and to collect the average heart rate for the exercise logs. Subjects from the study on swimmers (n=11) wore a WHOOP band (WHOOP Inc., Boston, MA, USA), and participants from the remaining studies (n=30) wore a Polar watch (Polar Vantage V2, Premium Multisport Watch, Polar, Kempele, Finland, or Polar Vantage M, Premium Multisport Watch, Polar, Kempele, Finland) and a Polar heart rate monitor (Polar H9, Heart Rate Sensor, Polar, Kempele, Finland). Exercise data was processed using the WHOOP application and the Polar Flow website and software (Polar Flow, Polar, Kempele, Finland).

3.6 Resting Metabolic Rate (RMR) and m/pRMR Ratio

Following a 12-hour fast and abstention of exercise for 24 hours, subjects reported to the laboratory between 0600 and 0900 hour for the energetic status assessment. Participants rested for 30-40 minutes in supine position for an acclimation period, and RMR was measured subsequently for 30-40 minutes via indirect calorimetry with a ventilated hood (SensorMedics Vmax Series; CareFusion,Yorba Linda, CA). Oxygen consumption and carbon dioxide production were measured every 30s, and RMR was calculated using the Weir equation (Weir, 1949) including only the datapoints where steady-state was achieved (VO_2 and VCO_2 variability <10% and respiratory quotient variability <5%). The ratio of the measured RMR to the predicted RMR (m/pRMR ratio) was calculated as the RMR measured with indirect calorimetry to the RMR estimated with four predictive equations: Harris-Benedict (Harris & Benedict, 1918), $Cunningham_{1980}$ (Cunningham, 1980), $Cunningham_{1991}$ (Cunningham, 1991), and the DXA-predicted equation (Elia, 1992; Hayes et al., 2002; Koehler et al., 2016).

3.7 Serum Triiodothyronine (TT3)

Blood samples were obtained from the antecubital vein, in a fasted state following the RMR measurement, with the use of blood collection tubes (BD Vacutainer; Becton, Dickinson and Company, FranklinLakes, NJ). Samples were allowed to clot at room temperature for a minimum of 30 minutes before being centrifuged for 15 minutes at 4°C (Eppendorf centrifuge 5804R; Eppendorf, Hamburg, Germany), aliquoted, and stored at -80 °C for future analysis. Competitive immunoassays were performed using a chemiluminescence immunoassay analyzer (Immulite; Siemens Healthcare, Erlangen, Germany). Analytical sensitivity for the assay is 35 ng/dL.

3.8 Questionnaires

DE behavior was assessed with well validated psychometric subscales. Subjects were required to complete the Three-Factor Eating Questionnaire-R21 (TFEQ-R21) (Cappelleri et al., 2009), the Eating Disorder Inventory – 3 (EDI-3) (Garner & Van Strien, 2004), the Drive for

Leanness (DL) scale (Garner & Van Strien, 2004), and the Drive for Muscularity (DM) scale (Garner & Van Strien, 2004). The following subscales were scored: Perfectionism (P), Body Dissatisfaction (BD), and Drive for Thinness (DT) from EDI-3; the Dietary Cognitive Restraint scale (DCR) from TFEQ-R21; and the DL and DM scales. Participants were grouped according to their DCR scores: men with a DCR score <13 were hypothesized to be at low risk for energy deficiency, and participants who scored ≥13 were hypothesized to be at a high risk for energy deficiency.

3.9 Statistical Analysis

Shapiro-Wilk tests were performed for EDI-3 subscales, DL, DM, TT3, and m/pRMR ratio to assess normal distribution. Differences between groups separated by DCR scores were investigated with T-tests, for variables that were normally distributed, and Mann-Whitney tests, for variables that were not normally distributed. Data are shown as mean±S.E.M.

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Chapter 4

Manuscript

<u>The relationship between eating behavior questionnaire scores and energy status in young exercising men</u>

4.1 Introduction

Disordered eating (DE) and eating disorders (ED) are common in athletes and can lead to energy deficiency (M. J. De Souza, Hontscharuk, Olmsted, Kerr, & Williams, 2007; Gibbs, Williams, Scheid, Toombs, & De Souza, 2011; Sim & Burns, 2021). Energy deficiency denotes the physiological condition characterized by suppressed metabolism (Anne B Loucks, 2003; A. B. Loucks & Heath, 1994) and can be assessed by dividing the measured resting metabolic rate (mRMR) of the participant by the predicted resting metabolic rate (pRMR) to develop the m/pRMR ratio. Beyond a suppressed metabolism, downstream effects of energy deficiency include detrimental effects to bone and reproductive health. In exercising women, individuals with a m/pRMR ratio closer to 1 were energy replete, where exercising women with a m/pRMR ratio below 0.9 or lower were energy deplete (M. J. De Souza et al., 2007). However, the exact cut-off varies depending on the equation utilized to calculate the m/pRMR ratio (Strock, Koltun, Mallinson, Williams, & De Souza, 2020; Strock, Koltun, Southmayd, Williams, & De Souza, 2020).

Metabolic hormones can also be studied to evaluate energy deficiency. One hormone of focus is triiodothyronine (TT3), its serum levels are used to assess the activity of the thyroid and its role in metabolism. Low serum TT3 can be indicative of energy deficiency. When experiencing bouts of undernourishment, exercising males experienced lower testosterone, insulin-like growth factor 1 (IGF-1), and TT3 serum concentration. Additionally, the male athletes experienced lower levels of fat-stores and an increased rate of protein catabolism (Friedl et al., 2000). However, when refed, exercising males' hormones recovered much faster than exercising females. Additionally, a study done on endurance trained male athletes showed that training caused hormonal disturbances that inhibited testicular function (Hackney, Sinning, & Bruot, 1988). Friedl et al. (2000) found that for men in multistressor environments, eating in a caloric deficit and enduring extreme exercise, metabolic hormones such as TT3, testosterone, and IGF-1 decreased, which adversely affected the bone health of the athletes. The study showed how rationing energy is far from ideal and is detrimental metabolism, reproductive health, and bone health (Friedl et al., 2000).

The Eating Disorder Inventory-3 (EDI-3) and the Three-Factor Eating Questionnaire (TFEQ) are psychometric tools that can be used clinically to assess disordered eating (DE) behavior (Cappelleri et al., 2009; Garner & Van Strien, 2004). The relationship between the TFEQ, EDI-3 scores, and m/pRMR ratios have not been thoroughly studied, especially in male athletes and young exercising men. However, males who participate in sports that emphasize or favor leanness or a weight class, such as running, long jump, high jump, ski jumping, gymnastics, wrestling, judo, karate, diving, or bodybuilding are at a higher risk for DE or eating disorder (ED) (Sundgot-Borgen & Torstveit, 2010). This finding could suggest that restricted eating with the goal of leanness for competition could lead to further DE pathologies if not caught at an early stage.

As we aim to identify behaviors associated with EDs, reliable surrogate indicators for energy deficiency allow for sports professionals to easily assess whether an athlete is at risk are necessary. M. J. De Souza et al. (2007) identified subclinical DE behaviors in female athletes and subsequent energy deficiency utilizing the DT subscale from the EDI-3. High DT ($\geq$7) and high dietary cognitive restraint (DCR) scores in the Exercising High DT group were indicative of individuals at risk for DE, which is consistent with prior studies (Garner, Garfinkel, & Bonato, 1987; McLEAN, Barr, & Prior, 2001)). The participants with high DT scores displayed markers of energy deficiency including m/pRMR ratios below 0.9, significantly lower TT3 concentrations, and significantly higher ghrelin levels (M. J. De Souza et al., 2007) . Additionally, high DT and high DCR are very highly associated (McLEAN et al., 2001; O'Connor, Lewis, & Kirchner, 1995; Otis, Drinkwater, Johnson, Loucks, & Wilmore, 1997; Sundgot-Borgen, 1994), implying that restricting food was a conscious action intended to keep a thin stature (Stunkard & Messick, 1985). Women who score high on both DCR and DT are more successful restrictive eaters and tend to diet with the goal to prevent weight gain compared to dieting to lose weight (Lowe, 1994; Safer, Agras, Lowe, & Bryson, 2004; Stunkard & Messick, 1985). This nuance is important as women who aim to prevent weight gain are typically already lean and successful at chronic restriction, putting them at risk for being energy deficient while those that diet to lose weight have not been as successful and thus are less likely to be at risk. While a high DT with concomitant high DCR is related to energy deficiency in athletes, this may not be the case in an individual with high DCR and normal DT (M. J. De Souza et al., 2007). A normal DT could imply that the individual is not successful at restraining energy intake, even if she has a high DCR score.

DCR scores, in relation to energy deficiency, can also provide indications of reproductive and bone health. In an observational study, Vescovi, Scheid, Hontscharuk, and De Souza (2008) evaluated the relationship of DCR with bone mineral density (BMD), bone mineral content (BMC), menstrual, and metabolic status in eighty-four physically active women in good health who ranged from 18-35 years old. When participants were split into quartiles based on DCR score, the high DCR group (DCR≥13) had lower total body and lumbar spine BMD, more prevalent infrequent menstrual periods (oligo-amenorrhea), and a m/pRMR ratio lower than all the other quartiles (DCR<13) (Vescovi et al., 2008). Thus, this indicates that a high DCR can suggest energy deficiency and consequently energy deficiency related reproductive and bone health outcomes.

While many female subjects have been readily studied, there is limited data on exercising men, especially data evaluating the relationships between the TFEQ and EDI-3 with energy deficiency. One study that utilized a cognitive restraint cut-off of ≥13 found that there were significant negative correlations between DCR scores above that threshold and the Harris-Benedict m/pRMR ratio in healthy male athletes (Jurov, Keay, Hadžić, Spudić, & Rauter, 2021). Since high DCR correlated with a low m/pRMR ratio, it was determined that DCR is associated with energy conservation symptoms. Mean EA measured in the study for the male athletes was lower than the threshold in females (30 kcal/kg FFM/day), suggesting that male endurance athletes may have a lower overall EA threshold than females do (Jurov et al., 2021). The finding that male athletes may require a lower EA threshold is also supported by the active males' metabolic resilience to low EA in Friedl et al. (2000). This knowledge can guide future studies when testing conditions to observe signs of low EA in active males.

The overall objective of our study was to determine if DCR is a discriminative factor between energy replete and energy deficient young exercising males. We hypothesized that: (1) young exercising males who scored ≥13 in the DCR subscale of the TFEQ will have lower TT3 and lower m/pRMR ratio compared to peers who scored <13 and (2) that young exercising males that scored ≥13 in the DCR subscale of the TFEQ will also have higher scores of DT, Drive for Leanness (DL), and Body Dissatisfaction (BD), but not of Drive for Muscularity (DM) and Perfectionism (P).

4.2 Methods

4.2A Experimental Design:

The present study reports preliminary findings from a data set derived from three studies: a cross-sectional study investigating energy status, metabolism, and stress in collegiate swimmers (n=11); a larger ongoing cross-sectional study investigating metabolism, reproductive function, stress, and bone health in young exercising men (n=22, 16 recreationally active men and 6 athletes); and an ongoing longitudinal study investigating metabolism, reproductive function, stress, and bone health in collegiate athletes across a competitive season, of which only the baseline measurement from male athletes has been used (n=8). The latter of the eight, five collegiate athletes were also enrolled in the cross-sectional study in active men; therefore, the final total sample size (n) was of 41 active young men. Participants from all three studies completed measurements of RMR, body composition with a DXA device, and serum total TT3, to investigate the relationship between the measured-to-predicted resting metabolic rate ratio (m/pRMR ratio) and TT3.

4.2B Study Participants:

Participants included 11 male swimmers, 14 male athletes, and 16 recreationally active men aged 18-33 years who habitually exercised (at least 150 minutes of purposeful exercise per week) and had body mass index (BMI) between 18.5 and 29.99 kg/m^2, and percent body fat (%BF) below 30%. Men included had peak aerobic capacity (VO_2 max) of at least 44 ml O_2/kg/min as determined with a graded treadmill test, except for the subjects in the swimmer's study (n=11), from whom VO_2 max was not obtained. Those that smoked or were taking medication that could alter metabolic or reproductive function were excluded.

4.2C Anthropometrics and body composition:

A physician's scale was used to assess body mass to the nearest 0.1 kg, and a stadiometer was used to assess subject height to the nearest 0.1 cm. A Dual-Energy X-Ray Absorptiometry (DXA) device (Hologic QDR Horizon W, X-Ray Bone Densitometer, Hologic, Bedford, MA) was used to assess body composition, i.e. total fat mass, lean body mass (LBM), fat-free mass (FFM), and %BF, performed by an International Society of Clinical Densitometry-certified technician.

4.2D Peak aerobic capacity (VO_2 max):

All subjects, except for the participants of the study on swimmers, performed a graded treadmill test to exhaustion for a measurement of VO_2 max. After a 2-min walking and jogging warm-up period, subjects were allowed to choose a speed to run at 0.0% grade. For the first six minutes of the test, grade was increased 2% every two minutes, followed by a 1% increase in grade every minute until volitional exhaustion was achieved. VO_2 and CO_2 were measured using a metabolic cart (SensorMedics Vmax Series; CareFusion,Yorba Linda, CA). At least two of the following criteria were achieved for the test to be considered valid, including a max heart rate, a RPE of at least 18, an RER >1.15, and a plateau in VO_2 uptake despite an increase in workload (Barker, Williams, Jones, & Armstrong, 2011).

4.2E Exercise Time:

To validate that participants were active, a minimum of 150 minutes of purposeful exercise weekly, participants were asked to record type, duration, and average hear rate for every exercise session practiced throughout seven consecutive days on exercise logs. Participants were asked to wear activity monitoring devices to record exercise sessions and to collect the average heart rate for the exercise logs. Subjects from the study on swimmers (n=11) wore a WHOOP band (WHOOP Inc., Boston, MA, USA), and participants from the remaining studies (n=30) wore a Polar watch (Polar Vantage V2, Premium Multisport Watch, Polar, Kempele, Finland, or Polar Vantage M, Premium Multisport Watch, Polar, Kempele, Finland) and a Polar heart rate monitor (Polar H9, Heart Rate Sensor, Polar, Kempele, Finland). Exercise data was processed using the WHOOP application and the Polar Flow website and software (Polar Flow, Polar, Kempele, Finland).

4.2F Resting Metabolic Rate (RMR) and m/pRMR Ratio:

Following a 12-hour fast and abstention of exercise for 24 hours, subjects reported to the laboratory between 0600 and 0900 hour for the energetic status assessment. Participants rested for 30-40 minutes in supine position for an acclimation period, and RMR was measured subsequently for 30-40 minutes via indirect calorimetry with a ventilated hood (SensorMedics Vmax Series; CareFusion,Yorba Linda, CA). Oxygen consumption and carbon dioxide production were measured every 30s, and RMR was calculated using the Weir equation (Weir, 1949) including only the datapoints where steady-state was achieved (VO_2 and VCO_2 variability <10% and respiratory quotient variability <5%). The m/pRMR ratio was calculated with indirect calorimetry to the RMR estimated with four predictive equations: Harris-Benedict (Harris & Benedict, 1918), $Cunningham_{1980}$ (Cunningham, 1980), $Cunningham_{1991}$ (Cunningham, 1991), and the DXA-predicted equation (Elia, 1992; Hayes et al., 2002; Koehler et al., 2016).

4.2G Serum Triiodothyronine (TT3):

Blood samples were obtained from the antecubital vein, in a fasted state following the RMR measurement, with the use of blood collection tubes (BD Vacutainer; Becton, Dickinson and Company, FranklinLakes, NJ). Samples were allowed to clot at room temperature for a minimum of 30 minutes before being centrifuged for 15 minutes at 4°C (Eppendorf centrifuge 5804R; Eppendorf, Hamburg, Germany), aliquoted, and stored at -80 °C for future analysis.

Competitive immunoassays were performed using a chemiluminescence immunoassay analyzer (Immulite; Siemens Healthcare, Erlangen, Germany). Analytical sensitivity for the assay is 35 ng/dL.

4.2H Questionnaires:

DE behaviors were assessed with widely validated psychometric subscales. Subjects were required to complete the TFEQ-R21 (Cappelleri et al., 2009) and the EDI-3 (Garner & Van Strien, 2004) the DL scale (Garner & Van Strien, 2004), and the DM scale (Garner & Van Strien, 2004). The following subscales were scored: P, BD, and DT from EDI-3; the DCR scale from TFEQ-R21; and the DL and DM scales. Participants were grouped according to their DCR scores: men with a DCR score <13 were hypothesized to be at low risk for energy deficiency, and participants who scored ≥13 were hypothesized to be at a high risk for energy deficiency. The score of 13 as a cut-off threshold was chosen following previous evidence suggesting that cognitive restraint ≥13 might be a useful marker for low EA in exercising women (Gibbs et al., 2011; Jurov et al., 2021).

4.2I Statistical Analysis:

Shapiro-Wilk tests were performed for EDI-3 subscales, DL, DM, TT3, and m/pRMR ratio to assess normal distribution. Differences between groups separated by DCR scores (high DCR was ≥13; normal DCR was <13) were investigated with T-tests, for variables that were normally distributed, and Mann-Whitney tests, for variables that were not normally distributed. Data are shown as mean±S.E.M.

4.3 Results

4.3A Descriptive Statistics of Study Participants:

Descriptive characteristics of exercising males are presented in **Table 2**. Study participants were classified as having normal DCR (score <13) or high DCR (score ≥ 13) depending on their EDI-3 questionnaire. Participants who had a normal cognitive restraint score (NCR) were 22.28±2.963 yr, were 180.897±6.8 cm, and weighed 78.93±10.51 kg with 19.031± 2.86% body fat, and had a BMI of 24.06±2.50 kg/m^2. The NCR athletes also had a lean body mass of 59.53±8.5 kg and fat free mass of 62.57±8.78 kg. Participants who had a high cognitive restraint score (HCR) were 22.5±4.815 yr, were 180.567±6.174 cm, and weighed 77.668±12.229 kg with 19.542± 3.558% body fat, and had a BMI of 23.755±3.334 kg/m^2. The HCR athletes also had a lean body mass of 59.981±7.799 kg and fat free mass of 62.928±8.204 kg. None of these measures were significant ($p>0.05$).

4.3B m/pRMR characteristics:

The NCR athletes presented with an m/pRMR ratio of 0.911±0.076 (Harris-Benedict), 0.960±0.080 (Cunningham_{1980}), 1.010±0.084 (Cunningham_{1991}), and 0.967±0.085 (DXA). The HCR athletes presented with an m/pRMR ratio of 0.912±0.099 (Harris-Benedict), 0.943±0.070 (Cunningham_{1980}), 0.993±0.069 (Cunningham_{1991}), and 0.931±0.084 (DXA). There were no significant differences between NCR and HCR groups' m/pRMR ratios ($p>0.05$).

4.3C Serum TT3 characteristics:

Mean serum TT3 concentrations in the NCR exercising males was 114.967±24.04 ng/dL compared to 112.267±12.565 ng/dL in the HCR group. No differences were observed between NCR and HCR groups ($p>0.05$). Additionally, there were no significant correlations between TT3 levels and the Harris-Benedict, $Cunningham_{1980}$, $Cunningham_{1991}$, and DXA calculated m/pRMR ratios ($p>0.05$).

4.3D Questionnaire Scores:

NCR participants scored a mean of 2.14±2.560, compared to a mean of 5.42±4.926 in the HCR group on the EDI-3 DT subscale, which was significant ($p=0.047$). On the EDI-3 P scale, the NCR group had a mean of 10.03±4.145 versus the HCR mean score of 11.83±5.149 ($p>0.05$). The NCR had a significantly lower mean EDI-3 BD score (4.59±4.997) compared to the HCR group (8.25±5.754) on the EDI-3 BD subscale ($p=0.048$). Lastly, the NCR group had significant lower mean scores on the DM scale (40.41±15.740 vs 52.25±11.717, $p=0.024$) and on the DL scale (34.52±11.230 vs 43.67±8.370, $p=0.015$). Additionally, there were significant positive associations existing between DCR score and DT ($r=.47$, $p=0.002$), DM ($r=.43$, $p=.005$), and DL ($r=.56$, $p<0.001$).

Table 2: Descriptive Characteristics of Males with High and Normal DCR Scores

Questionnaire	All Participants		Normal DCR (≤13)		High DCR (>13)		p-value
	Mean±SD	N	Mean±SD	N	Mean±SD	N	
Age (yr)	22.34±3.54	41	22.28±2.963	29	22.5±4.815	12	0.856
Height (cm)	180.8±6.562	41	180.897±6.8	29	180.567±6.174	12	0.886
Body Weight (kg)	78.562±10. 897	41	78.93±10.51	29	77.668±12.229	12	0.740
BMI (kg/m^2)	23.974±2.73	41	24.06±2.50	29	23.755±3.334	12	0.745
Lean Body Mass (kg)	59.660±8.204	41	59.53±8.5	29	59.981±7.799	12	0.874
Fat Free Mass (kg)	62.678±8.515	41	62.57±8.78	29	62.928±8.204	12	0.906
Body Fat (%)	19.18±3.047	41	19.031±2.86	29	19.542±3.558	12	0.631
Harris-Benedict Ratio	0.911±0.083	41	0.911±0.076	29	0.912±0.099	12	0.974
Cunningham$_{1980}$ Ratio	0.955±0.077	41	0.960±0.080	29	0.943±0.070	12	0.522
Cunningham$_{1991}$ Ratio	1.005±0.079	41	1.010±0.084	29	0.993±0.069	12	0.535
DXA Ratio	0.957±0.086	41	0.967±0.085	29	0.931±0.084	12	0.224
TT3 (ng/dL)	114.177±21.202	41	114.967±24.04	29	112.267±12.565	12	0.641

Table 3: Mean Questionnaire scores for Males with High and Normal DCR Scores

Questionnaire	All Participants	Normal DCR (≤13)	High DCR (>13)	p-value
Drive for Thinness (DT)	3.10±3.680	2.14±2.560	5.42±4.926	**0.047**
Body Dissatisfaction (BD)	5.66±5.425	4.59±4.997	8.25±5.754	**0.048**
Perfectionism (P)	10.56±4.472	10.03±4.145	11.83±5.149	0.246
Drive for Muscularity (DM)	43.88±15.521	40.41±15.740	52.25±11.717	**0.024**
Drive for Leanness (DL)	37.20±11.194	34.52±11.230	43.67±8.370	**0.015**

4.4 Discussion

In our study, we investigated the relationship between DCR scores, m/pRMR ratios, TT3, and DT, DM, DL, BD, & P scores in young exercising males. It was hypothesized that males with a score ≥13 on the TFEQ DCR subscale would have lower serum TT3 concentrations and m/pRMR ratios than the NCR group. However, there were no significant differences in TT3 and m/pRMR ratios between the groups. Overall, our results suggest that DCR in young exercising males is not indicative of a higher risk for energy deficiency or of having suppressed concentrations of TT3. Combined with the resilience of male metabolic hormones, DCR scores in the participants may not have been high enough to observe the chronic deficits expected. However, if DCR scores were high enough, it is also possible that exercising males did not experience low EA conditions long enough to start to see detrimental effects in energy conservation.

Our study demonstrated a positive association between DCR and DT ($r=.47$, $p=0.002$), DM ($r=.43$, $p=.005$), and DL ($r=.56$, $p<0.001$), as hypothesized. The associations show that HCR individuals will likely have high DM, DL, or DT. The P subscale was not significantly correlated with DCR, potentially because perfectionism does not necessarily require restrictive eating. DT, DL, and DM all require eating to achieve a certain physique, which can lead to restrictive or DE. P is a multidimensional measure, and a common sports-related component of P is self-esteem. An athlete with higher self-esteem may exhibit positive perfectionism, a trait where it is more likely that an individual engages in behaviors for the positive consequences, not to avoid negative consequences. Low self-esteem could be a risk factor for BD, DE, but it is not perfectionism that is directly responsible for the restricted energy intake and lowered EA (Petisco-Rodríguez, Sánchez-Sánchez, Fernández-García, Sánchez-Sánchez, & García-Montes, 2020). The HCR group had significantly higher mean DM (p=0.024), DL (p=0.015), DT (p=0.047), and BD (p=0.048) than the NCR group. While both DT and DM are associated with binge eating, research suggests that men who engage in DM behaviors do not purge like those who engage in DT behavior (McCreary & Sasse, 2000). Moreover, the DM scale does not necessarily measure the adherence to behavior to gain muscle mass, but to a desire to have a more muscular body, or a preference for muscular bodies rather than thinner bodies. In males, DM is more common than DT, so DM could demonstrate exercising males' abilities to control their eating habits and sculpt their bodies (Bratland-Sanda & Sundgot-Borgen, 2013). DL is also a common characteristic observed in males. DL is classified as an interest in having low body fat along with toned muscles and could relate to DCR because athletes strive to achieve a desired body weight through restrained eating (Smolak & Murnen, 2008). DL is a distinct measure from DT and DM, as DL, DT, and DM had moderate correlations. All three measures contribute to body image in an individual (Smolak & Murnen, 2008). BD was another questionnaire that had significantly higher scores in the HCR group than the NCR group. BD is a measure of negative body image and is considered to be a preliminary symptom to EDs (Fortes & Ferreira, 2011). BD, along with P and self-esteem have been shown to have significant impacts on bulimic symptoms (Vohs et al., 2001). Not only was the mean BD score significant, but the association between BD and DCR showed that higher BD could make an individual more likely to engage in DCR. Overall, the HCR group had higher means in DM, DL, DT, and BD, showing that the HCR group scored higher on these questionnaires that the NCR group.

A strength of our study is that the athletes and recreationally exercising men vary in exercise level and specialization. It is difficult to measure the energy levels of male athletes, and having more than one sport in our sample gives us a better idea of how DCR scores and EA can affect more than one type of athlete. Our approach evaluates the relationship between psychological factors related to DE and energy deficiency in young exercising males. Additionally, measuring TT3 concentrations in athletes is a reliable method to assess energy status, as TT3 concentration levels have been shown to decrease in athletes who experience EDs (Elliott-Sale, Tenforde, Parziale, Holtzman, & Ackerman, 2018; A. Loucks et al., 1992). The psychometric scales used in our study are also widely used and validated to assess pathological eating behaviors (Garner & Van Strien, 2004). However, there were some limitations to our study.

Measuring exercise level is a challenge because participants self-reported their activity in logs. The participants were also responsible for wearing the WHOOP bands and Polar watches, and inaccurate measures could result from false activity logs, incorrectly wearing, or failing to always wear the device. This source of error was mitigated by checking the reports on the WHOOP and Polar software to attest that the participants wore the device correctly. Additionally, there is more than one method that can be used to assess energy status. Our study used laboratory-based measurements, the m/pRMR ratio, and serum TT3 to identify participants at risk of being energy deficient. Four different m/pRMR ratios were calculated including the Harris-Benedict (Harris & Benedict, 1918), Cunningham_{1980} (Cunningham, 1980), Cunningham_{1991} (Cunningham, 1991), and the DXA-predicted equation (Elia, 1992; Hayes et al., 2002; Koehler et al., 2016). Additionally, in previous studies in exercising women, a ratio less than 0.90 served as an indicator of energy deficiency (M. J. De Souza et al., 2007; Mary Jane De Souza et al., 2007; Mary Jane De Souza et al., 2008; Gibbs et al., 2011; Strock, Koltun, Mallinson, et al., 2020; Strock, Koltun, Southmayd, et al., 2020). Knowing that males are more resilient to consequences of energy deficiency (Friedl et al., 2000), the ratio may have needed to be lower to observe any significant findings between the relationship of DCR and m/pRMR. Additionally, we did not separate the athletic and non-athletic population to perform an analysis, so we do not know which population may have had more prevalent energy deficiency.

Overall, our findings provide evidence of differences between DCR threshold groups and their DT, DL, BD, and DM scores. In contrast to our hypothesis, the HCR group did not show any significant differences from the NCR group in m/pRMR ratios or TT3 concentrations. However, the mean scores of DM, DL, and BD were higher in the HCR group compared to the NCR group, supporting our hypothesis. Implications of our study include that the HCR group scored differently than the NCR group on some measures, but the cut-off may not have been extreme enough to observe significant differences. Future studies should be aimed at adjusting this cut-off to observe more significant differences in psychological factors and energetic status. Evaluating eating behaviors via the questionnaires would be beneficial for male athletes to ensure they reach optimal performance without being at risk for the Male Athlete Triad. Further research must be conducted to investigate the relationship between psychometric subscale scores and energy deficiency in men.

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Chapter 5

Summary, Conclusions, and Implications

Male athletes who participate in sports that emphasize leanness are more likely to be at risk for developing eating disorders (EDs) or disordered eating (DE) habits (Nattiv et al., 2021). DE is one of the three symptoms presented by the Male Athlete Triad, which consists of low energy availability (EA), impaired bone health, and a suppression of the hypothalamic-pituitary-gonadal (HPG) axis (Nattiv et al., 2021). Energy deficiency is a consequence of restrictive eating habits and failure to match dietary intake to energy expenditure (Torstveit & Sundgot-Borgen, 2005). Chronic energy deficiency in male athletes suppresses metabolic hormones and reproductive functioning to save energy for thermoregulation, cellular maintenance, and locomotion (Wade, Schneider, & Li, 1996), all functions that are essential to survival. To date, the impact of energy deficiency in male athletes is understudied and not well understood.

The purpose of our study was to examine if energetic factors like low EA, low resting metabolic rate ratios (m/pRMR ratios), and low triiodothyronine (TT3) could indicate an athlete's energy status. We used psychometric measures including Drive for Thinness (DT), Drive for Leanness (DL), Drive for Muscularity (DM), Perfectionism (P), Dietary Cognitive Restraint (DCR), and Body Dissatisfaction (BD) to see if there were any relationships between pathological eating behaviors and the markers of energy deficiency in the participants. We assessed athletes and split them into groups based on high ($\geq$13) or normal (<13) DCR. We examined the effects of energy status on 16 active men and 25 male athletes aged 18-33 years who were exercising (at least 150 minutes of purposeful exercise per week) and had body mass index (BMI) between 18.5 and 29.99 kg/m^2 and percent body fat (%BF) below 30%. It was initially hypothesized that young exercising men that scored ≥13 on the DCR subscale of the TFEQ will have lower TT3 concentrations and lower m/pRMR ratio compared to peers who scored <13 on the DCR subscale. It was also hypothesized that young exercising men that scored ≥13 on the DCR subscale of the TFEQ will have higher scores of DT, DL, and BD, but not of DM and P.

Overall, our results did not provide evidence of a relationship between DCR and m/pRMR ratios, low EA, or low TT3 levels. Of the four m/pRMR ratio calculation equations used, there were no significant differences observed between normal cognitive restraint participants (NCR) and high cognitive restraint participants (HCR). Additionally, there was no significant difference between the TT3 levels of the NCR group versus the HCR group. There were also no significant correlations between TT3 levels and Harris-Benedict, Cunningham_{1980}, Cunningham_{1991}, and DXA calculated m/pRMR ratios. NCR participants scored insignificantly on the EDI-3 DT and EDI3 P scales compared to HCR athletes. However, the NCR group had significantly lower mean EDI-3 BD score compared to the HCR group. The NCR group also had significantly lower mean scores on the DM and the DL scale than the HCR participants. Lastly, we found that there were significant associations existing between mean DCR scores and DT, DM, and DL.

Contrary to our hypothesis, exercising men that scored ≥13 on the DCR questionnaire did not have lower TT3 concentrations and lower m/pRMR ratios compared to peers who scored <13. It did not appear that DCR could be indicative of low EA and energy deficiency in male athletes. We also found that athletes that scored higher on the DCR questionnaire had higher levels of DM, DL, and BD, but not DT and P. Our hypothesis was correct in predicting that DL and BD would be related to high DCR, but not about DM, P, or DT. While there could be many factors responsible for this, it could be possible the DM scale does not necessarily measure the adherence to eating behavior to gain muscle mass, but simply a desire to have a more muscular body. In males, DM is more common than DT, so DM could demonstrate exercising males' abilities to control their eating habits and sculpt their bodies (Bratland-Sanda & Sundgot-Borgen, 2013). High DL is also common in males, as it is a combination of DT and DM. DL could be related to DCR because lean physiques are typically a result of athletes attempting to achieve a desired appearance, with restrained eating and tracking food (Smolak & Murnen, 2008). BD is another aspect where we observed high DCR, which could be because BD is one of the first symptoms observed in the onset of EDs. Finding that the association between DCR and BD is high illustrates how DCR can be related to DE, energy deficiency, and EDs (Fortes & Ferreira, 2011).

In summary, energy deficiency was not associated with higher levels of DCR. TT3 levels and EA were also unrelated, contrary to our hypothesis. However, HCR athletes had higher BD, DM, and DL scores with significant associations between DCR and DT, DM, and DL scales. We suggest conducting future research on the relationship between DCR and psychometric factors like DT, DM, DL, and BD, and if psychometric factors may be more likely to indicate risk of energy deficiency in exercising males. Further research is necessary to determine more associations between the questionnaire variables in a larger and more diverse group of exercising male subjects.

5.1 References

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Wade, G. N., Schneider, J. E., & Li, H. Y. (1996). Control of fertility by metabolic cues. *Am J Physiol, 270*(1 Pt 1), E1-19. doi:10.1152/ajpendo.1996.270.1.E1

ACADEMIC VITA of Jessica Ware

Education & Awards/Honors
THE PENNSYLVANIA STATE UNIVERSITY, University Park, PA
B.S. in Kinesiology, May 2024
College of Health and Human Development
Undergraduate Certificate in Diversity Studies

Related Coursework: Biomechanics, Anatomy & Physiology, Physics, Exercise Physiology, Motor Control, Nutrition, Statistics, Introductions to Kinesiology, Biobehavioral Health, General Chemistry, Biodiversity, Organic Chemistry, Exercise Psychology, Molecular Biology, Biochemistry, Sociology, Human Growth & Development, Physical Activity in Diverse Populations, Meaning, Ethics, and Movement, Deaf Culture, Introduction to Autism and Spectrum Disorders, Women's Studies

Certifications: Adult and Pediatric First Aid/CPR/AED, Medical Scribe, HIPAA, Biomedical Human Subjects (IRB) Course, Biosafety Training, OSHA Bloodborne Pathogens, GCP - Social and Behavioral Research Best Practices for Clinical Research, Good Laboratory Practice (GLP), EHS Initial Lab & Research Safety Training (PSU), American Heart Association Basic Life Support (AHA BLS) Provider

Honors:
- Dean's List PSU, Fall 2020, Spring 2021, Fall 2021, Spring 2022, Fall 2022, Spring 2023, Fall 2023
- Academic All-American 2022-2023 (American Collegiate Hockey Association)
- AED National Health Preprofessional Honor Society, Spring 2023
- National Society of Leadership and Success, Spring 2021
- President's Award, Fall 2020

Health and Science Related Experience
UHS Clinic Intern, University Health Services at PSU, Spring 2023-present
- Assist in patient intakes, including taking vital signs, and documenting reasons for visit and allergies prior to physician consultation.
- Shadow ultrasound and procedures taking place within the clinic.

Research Assistant, Women's Health and Exercise Lab (WHEL) at PSU, 2022-present
- Aid PhD students in numerous studies including male and female athlete energy deficiency and first-year student metabolism.
- Collect data, participate as a subject when graduate students need to learn how to use a new device (e.g. DXA scan) and help around the lab by cleaning and organizing materials.
- Work on my honors thesis with the aim to determine a relationship between drive for leanness, which is a composite score of drive for muscularity and thinness, and energy deficiency in male athletes.

Teaching and Learning Assistant, Pennsylvania State University, University Park, PA, Fall 2021-present
- Teach lab sections of Biology 162 and Biology 164: Anatomy and Physiology.

- Responsibilities include creating quizzes and delivering course material for each lab block, host extra help in office hours and guide students to key learning strategies throughout the course.
- Attend class sessions and host office hours to help students in Chemistry 202 (Organic Chemistry).

Hospital Shadowing, San Camillo Forlanini Hospital, Summer 2023

- Observe surgical procedures in Maxillo-facial, Ophthalmology, and Cardiothoracic Departments.
- Learn different techniques for facial realignment, cataract surgery, and bypass surgery.
- Learn about the culture of healthcare in Italy, as well as the culture outside of the hospital setting.

Shadowing, Hospital for Special Surgery (HSS) & WestMed Medical Group, Summer 2022 & 2023

- Shadow orthopedic surgeon throughout the day (HSS).
- Learn about the importance of scans and the physical exam.
- Shadow a nephrologist throughout the day (WestMed).
- Learn about blood testing, the physical exam, and dialysis.

Physical

- Paired with a Physical Therapist to work with the patients that they see.
- For the second half hour of each visit, help patients with the exercises prescribed by the Physical Therapist.

Leadership and Coaching Experience

Member, PSU Women's Club Ice Hockey, 2020-present

- Attend practices twice weekly and 4-5 weekends of games per semester.
- President & Captain 2023-2024
    - Elected to serve as President.
    - The responsibility includes hiring and communicating with coaches and organizing home events by scheduling referees, EMTs, and ice.
    - Assume jobs of the coach this season which include coordinating with 9-10 other teams' coaches in the league to schedule games, registering the team and players for the league and USA hockey, planning and running practices and off-ice sessions, and attending league coaches' meetings.
    - Work closely with club sports to ensure the team is on a good track by attending leadership meetings, seminars, weekly check-ins, and filling out forms.
- Recruitment Chair 2023-2024
    - In charge of emails, calls, and setting up meetings with potential recruits.
    - Organize visits with the recruits on campus.
- Vice President 2022-2023
    - Elected to serve as the Vice President.
    - The responsibility entails taking care of everything related to travel including coordinating buses, booking hotels, and calling restaurants for our trips.
    - Must fill out numerous forms and attend meetings for and with club sports.

Member, PSU Women's Club Lacrosse, 2021-present

- Attend practices three times weekly and tournaments 2-3 weekends per semester.

Assistant Lacrosse Coach, Greenwich Youth Lacrosse, Greenwich, CT, Spring 2019-2020

- Assist at tryouts, practices, and games for a youth team in Greenwich by running drills and helping to choose lineups.
- Coach a GYL 8th grade travel team, attended and assisted in practices and traveled to games all around Fairfield County in Connecticut.

Additional Experience and Volunteering

Food Drive Coordinator & Volunteer, Lion's Pantry, University Park, PA, Spring 2023-present

- Communicate with organizations on campus to organize food drives for the pantry.
- Propose new ideas for how to implement more food drives with items that are in high demand.
- Attend weekly executive meetings and communicate conversations with the board.
- Help organize donations and restock shelves and put together orders to be distributed during the week.

Camp Counselor, Greenwich Country Club, Greenwich, CT, Summer 2019, 2021, 2022

- Organize arts and crafts, swimming, and other athletic activities for 5–6-year-olds and 9-10-year-olds
- Also responsible for the safety and well-being of all kids in the camp.
    - Note: Was planning to do this in the Summer of 2020, but it was canceled due to COVID-19

Hostess, Zody's 19th Hole Restaurant, Stamford, CT, Summer 2020

- In charge of organizing the seating and assigning waiters and waitresses to tables
- Handle take-out orders over the phone.