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Examining cognitive and behavioral inflexibility: A transdiagnostic process underpinning maladaptive exercise behaviors and attitudes

by

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Abstract

Objective: Cognitive and behavioral inflexibility, or the inability to respond flexibly and adaptively to changing environmental demands, are hallmark features of eating disorders (ED). Individuals with EDs exhibit inflexibility across domains, often including in exercise behaviors, manifesting as exercise dependence and rigid workout routines. The purpose of this study was to assess how different motives for exercise are differentially associated with cognitive and behavioral flexibility, a marker of EDs. To the extent that inflexibility in exercise is a risk factor and symptom of disordered eating, increasing cognitive and behavioral flexibility as it relates to physical activity may be an effective point of intervention for prevention and treatment of eating-related pathology. Method: Undergraduate students (n = 287, Mage = 19.2 years, 62.0% female, 52.6% white) completed validated measures quantifying exercise dependence and dimensions of intuitive exercise, as well as the Eating Disorder Flexibility Index (EDFLIX), a self-report measure of general and eating disorder-specific flexibility, and the Wisconsin Card Sorting Task (WCST), an objective test of cognitive and behavioral flexibility. Results: There were statistically significant differences between the Exercise Dependence Scale (EDS-21) “at risk for dependence” group and both “nondependent” groups in WCST perseveration errors, with the “at risk” group making the most mistakes. There was also a significant multivariate main effect of exercise dependence on EDFLIX general and ED-specific flexibility; with the “asymptomatic” group exhibiting significantly greater flexibility on the “Food & Exercise” subscale than the “at risk for dependence” and “nondependent symptomatic” groups. Intuitive Exercise Scale “emotional exercise,” “mindful exercise,” and “body trust” subscales were significant predictors of general flexibility, accounting for 18.8% of variance in EDFLIX global scores. Discussion: Findings suggest greater flexibility in those endorsing intuitive exercise, and decreased flexibility in those
endorsing rigid exercise and symptoms of exercise dependence, thus pointing to inflexibility as a transdiagnostic factor underpinning both maladaptive exercise and EDs. Research suggests that cognitive and behavioral inflexibility can be intervened upon transdiagnostically. Thus, targeting inflexibility in exercise may be an important point of intervention to increase eating-related flexibility and alleviating ED pathology.

*Keywords: exercise, cognitive flexibility, behavioral flexibility, Wisconsin Card Sort, eating disorders*
Introduction

Executive functions are important mental skills that include domains such as working memory, decision making, and cognitive flexibility (Diamond, 2014). Deficits in executive function impede one’s ability to effectively coordinate and process conflicting information, make well-reasoned decisions, focus on goals, override impulses, and consequently control behavior (Johnson, 2016; Snyder et al., 2015). Executive function deficits and abnormalities play a role in risk for and maintenance of psychopathology across the full range of mental health disorders (Aldao et al., 2010; Bloemen et al., 2018; Diamond, 2014; McTeague et al., 2016; Snyder et al., 2015), underpinning the core symptoms of many disorders, such as ritualistic behavior and weak central coherence, and impede the therapeutic process (Aloi et al., 2015; Dahlgren et al., 2019; Mohlman & Gorman, 2005).

Psychological inflexibility is a manifestation of exaggerated cognitive control and includes both cognitive and behavioral inflexibility, appearing as perseverative and rigid behaviors to changing rules (Alcaraz-Ibañez et al., 2018). Cognitive inflexibility is conceptualized as an inability to respond flexibly to one’s changing environment and internal states, leading to rigid behaviors in response to difficult emotions and cognitions (Dahlgren et al., 2019; Merwin et al., 2010). Research has revealed cognitive inflexibility as a predominant executive function deficit in a number of highly comorbid disorders, including but not limited to social anxiety, depression, obsessive-compulsive disorder, substance abuse, and eating disorders (ED) (Johnson, 2016; Merwin et al., 2010). One expression of inflexibility is rule-based insensitivity, an overreliance on rules for behavior, and a failure to consider one’s environment and experience and adapt actions flexibly to meet dynamically changing demands (Wulfert et al., 1994). Research has shown that individuals may initially develop such a rigid application of
rules for behavior to minimize uncertainty and thus anxiety by providing an illusion of control (Merwin et al., 2010). This inflexibility is thus intended to minimize undesired outcomes, such as anxiety in the presence of food, but in actuality leads to dysfunctional and harmful outcomes, such as restrictive eating.

High rates of comorbidity among mental health disorders indicates value in intervening on transdiagnostic processes such as inflexibility. Prior research suggests that mindfulness interventions and cognitive remediation therapy (CRT) may increase cognitive flexibility across psychopathology, including anxiety and eating disorders (Brockmeyer, et al., 2014; Chiesa et al., 2011; Dahlgren & Rø, 2014; Merwin et al., 2010; Tchanturia et al., 2013).

Neurobiological Substrates of Cognitive Flexibility

The neurobiological basis for deficits in cognitive flexibility is not fully established, but several studies point to a causal role of functional abnormalities in fronto-striato-cortical and thalamic circuits (Marsh et al., 2009; Friederich & Herzog, 2010). The striato-corticol pathways can be differentiated into the ventral and dorsal pathways. The ventral pathway includes the amygdala, anterior insula, ventral anterior cingulate cortex (ACC) and orbitofrontal cortex (OFC), while the dorsal pathway involves the dorsolateral prefrontal cortex, the parietal cortex, and the dorsal insular region (Friederich & Herzog, 2010). Impaired flexibility in the acute phase of anorexia nervosa (AN), for example, is associated with hypoactivation in the ventral anterior cingulate-striato-thalamic loop (Zastrow et al., 2009). Research has shown that the modulation of striato-cortical loops by ascending neurotransmitters including dopamine, noradrenaline, and serotonin, may also impact cognitive inflexibility (Friederich & Herzog, 2010). Behavioral inflexibility is similarly associated with hypoactivation of the fronto-striato-thalamic network, which includes the thalamus, ventral striatum, and rostral anterior cingulate cortex (Friederich &
Herzog, 2010). Ultimately, findings show that both cognitive and behavioral inflexibility are partially promoted through abnormal functioning in striato-cortical pathways.

**Inflexibility in Eating Disorders**

Psychological inflexibility, including cognitive and behavioral inflexibility, is a prominent feature of eating disorders (Friederich & Herzog, 2011; Merwin et al., 2010; Wang et al., 2019). This inflexibility appears transdiagnostically across EDs, as extreme perseverative behaviors, preoccupation with food, rigid rule following including strict food rules, rigid daily routines, and difficulty using alternative coping strategies (Roberts et al., 2010; Wang et al., 2019; Wang et al., 2019; Wu et al., 2014). Psychological inflexibility has received particular attention as a mechanism that increases risk for and influences the course of ED illness, with the principal symptoms of EDs seemingly all motivated by inflexibility (Roberts et al., 2010). Prior work has shown that increased inflexibility is associated with more severe ED rituals and increased illness duration (Roberts et al., 2010; Thogersen-Ntoumani & Ntoumani, 2006).

Furthermore, research suggests that inflexibility may be a trait marker or endophenotype in anorexia nervosa (Danner et al., 2012; Roberts et al., 2007; Holliday et al., 2005; Zastrow et al., 2009).

Individuals with EDs have a desire to control their internal emotional states and suppress negative emotions, leading to the development of rigid and over-controlled thoughts and behaviors, including excessive exercise and fasting, in an attempt to control uncontrollable events and temporarily alleviate negative emotional experiences, unfortunately leading to sometimes fatal outcomes in the long term (Birmingham et al., 2005; Merwin et al., 2010). The high degree of comorbidity between EDs and other disorders in which cognitive inflexibility
plays a key role, such as anxiety disorders, emphasizes the importance of addressing cognitive inflexibility as a transdiagnostic mechanism in EDs and co-occurring conditions.

The executive function abnormalities characteristic of EDs are especially pronounced in malnourished states. When malnourished, the brain is not adequately fueled, leading individuals with AN to exhibit diminished executive functioning, including difficulties with set-shifting, contextual integration, and decision making (Bolton et al., 2014; Klump et al., 2009; Pender et al., 2014; Zastrow, 2009). Importantly, research comparing flexibility in the acute underweight stage of AN with those who are weight restored is inconclusive, with some research suggesting inflexibility is exaggerated in the acute stage of illness (Tchanturia et al., 2013), and other research showing limited or no differences, suggesting inflexibility is an endophenotype (Miles et al., 2020). However, studies have shown that therapeutic processes, including CRT, can increase inflexibility and thus progress treatment (Leppanen et al., 2018).

**Links between maladaptive exercise and EDs**

Exercise is generally considered healthy, as it contributes to improved physical health, and adaptive, as it succors one’s ability to cope with stress, but can also become dysfunctional. Exercise dependence is conceptualized as a compulsive inclination to engage in physical activity, despite barriers including physical injury, and to the detriment of one’s physical health, and social or occupational functioning (Blaydon et al., 2004). On the other end of the spectrum, mindful or intuitive exercise involves attending to one’s bodily cues for determining when to initiate or stop exercise (Reel et al., 2016). Maladaptive exercise, including rigid routines around physical activity and exercise dependence, commonly occurs with EDs, and may be a symptom of subclinical EDs as well (Bamber et al., 2000; Cook et al., 2015). While research has emphasized the frequency and importance of relationships between maladaptive exercise and
eating behaviors, this relationship is in need of a more nuanced understanding. Specifically, there is limited research examining the relationship between flexibility and exercise, and the role inflexibility may play in underpinning and maintaining maladaptive behaviors. Pathological exercise and eating behaviors are often cyclically involved and inflexibility may be the transdiagnostic mechanism underlying both. To date, one study has examined relationships between orthorexia symptoms and cognitive inflexibility and found no association with cognitive flexibility as an executive function deficit (Hayatbini & Oberle, 2019). A second study examining exercise addiction and flexibility in recreational endurance exercisers found that psychological inflexibility accounted for 30% of the variance in exercise addiction (Alcaraz-Ibáñez et al., 2018).

An individual’s relationship with and motivations for exercise may at least partially determine risk for the development of maladaptive exercise behaviors, including dependent and rigid exercise. Adaptive motives for exercise, including health or social reasons, are associated with more favorable outcomes, including more mindful exercise (Ramsey, 2018). Furthermore, research has shown that emotion-based motives for exercise (e.g. to decrease stress) may be adaptive when linked with intuitive, mindful, and flexible exercise behaviors (Reel et al., 2016). Appearance-based motives for exercise, on the other hand, are typically more maladaptive and may be associated with dysfunctional exercise, including exercise dependence and rigid routines (Thome & Espelage, 2007; Vartanian et al., 2012). For instance, desire to control weight and shape is a transdiagnostic motive driving both maladaptive exercise and eating behaviors (Blaydon et al., 2004).

Among athletes, eating pathology is often secondary to and motivated by an initial desire for increased sports performance and belief that body shape and weight directly impact
performance (Krentz & Warshburger, 2013). It follows that individuals who participate in sports that have a focus on weight or body type (e.g. wrestling or bodybuilding), and aesthetic focused sports (e.g. dancing, figure skating, gymnastics, and diving) are more at risk for developing maladaptive eating behaviors (Krentz & Warshburger, 2013). While disordered eating more frequently affects athletes in sports that emphasize an ideal body shape or weight, no sports are exempt; research has shown that athletes are more at risk for ED pathology than nonathletes (Smolak et al., 2000). In general, athletic environments may encourage maladaptive eating and exercise behaviors to increase physique and competitiveness (Blaydon et al., 2004; Thompson & Sherman, 1999).

Despite these findings about maladaptive exercise behaviors and motives in EDs, research has yet to explore underlying flexibility as a link between adaptive motives for exercise and lower eating-related pathology. This research begins to shed light on associations between exercise and cognitive and behavioral inflexibility, specifically examining how adaptive vs. maladaptive exercise behaviors and motives are differentially associated with flexibility. I hypothesize that individuals who report more intuitive and mindful and less rigid relationships with exercise will exhibit increased flexibility in cognitions and behaviors, whereas individuals endorsing maladaptive exercise behaviors and motives may exhibit low flexibility. EDs have the highest mortality rate of any mental health disorder (Birmingham et al., 2005). As maladaptive exercise may be a subclinical risk factor for the development of EDs and a maintenance factor for pathological eating, understanding this relationship may help facilitate the design of interventions targeting maladaptive exercise behavior in both clinical and subclinical populations.
Research has well-established cognitive and behavioral inflexibility as a transdiagnostic process maintaining ED symptoms, and shown targeting inflexibility is an effective treatment (Brockmeyer et al., 2014; Merwin et al., 2010; Wang et al., 2019; Tchanturia et al., 2012). Importantly, research suggests that flexibility can be targeted transdiagnostically, such that targeting flexibility for one behavior may increase flexibility for other behaviors as well (Timko et al., 2018). Cognitive remediation therapy (CRT), which includes completing mind games such as illusions and reflecting on thought processes, helps individuals develop increased flexibility around food without directly targeting flexibility around eating-related stimuli (Timko et al., 2018). Individuals exhibiting maladaptive eating are likely more rigid in their exercise behaviors as well. Therefore, for individuals already struggling with eating disorder symptoms, intervening to increase flexibility in exercise may be one way to increase eating-related flexibility without directly intervening on food-related behaviors. Current treatments for EDs are limited, and exploring possible adjunctive approaches is requisite. Importantly, CRT explicitly targets inflexibility outside of food and eating, often making it easier for patients to engage in the therapy (Timko et al., 2018). Reducing rigidity around exercise may therefore be a less aversive approach to targeting inflexibility in EDs.

Defining and Measuring Psychological Flexibility

Psychological flexibility can be differentiated into cognitive and behavioral domains. Set-shifting, which assesses flexibility in response to changing rules, is a neuropsychological marker of flexibility and is frequently assessed through the Wisconsin Card Sorting Task (WCST) (Friederich & Herzog, 2010). Numerous studies have revealed that individuals with EDs make more errors in set-shifting tasks due to rule-based insensitivity (Merwin et al., 2010; Roberts et al., 2007). Behavioral inflexibility materializes as perseverative behaviors and is typically
measured by observing an individual’s ability to inhibit an impulse and perform an alternative behavior (Zastrow et al. 2009). Studies have shown that patients with EDs make more perseverative errors, meaning they engage in the impulse rather than alternative behavior more often than controls (Roberts et al., 2007; Tchanturia et al., 2012).

Though widely used, common measures of cognitive and behavioral flexibility have notable limitations. Neuropsychological task paradigms capture other domains of cognitive functioning as well, such as working memory, and are not designed to isolate inflexibility as a single marker (Friederich & Herzog, 2010). Furthermore, neuropsychological tasks may not capture and predict deficits in everyday functioning (Dahlgren et al., 2019). Additionally, ED specific flexibility is not captured by neuropsychological tasks. Finally, the administration of these tasks is time consuming and requires advanced training.

There are several self-report measures of general cognitive and behavioral flexibility that capture the subjective experience of inflexibility (Dahlgren et al., 2019). However, while inflexibility likely appears in all aspects of life (e.g. housework or strict rules for social interactions), it is unclear if these measures are suitable for capturing ED-specific rigidity, such as strict food rules, ritualized weighing, and inflexible exercise routines (Dahlgren et al., 2019; Wu et al., 2014). The Eating Disorder Flexibility Index (EDFLIX) is a relatively new measure of both general and ED specific flexibility that has demonstrated good psychometric properties in initial research (Dahlgren et al., 2019). It has yet to be explored in relation to rigid exercise behaviors characteristics of EDs.

To our knowledge, no studies to date have examined both self-report and objective measures of psychological inflexibility among differing exercise motives and behaviors in a non-clinical population. Studies have shown weak correlations between self-report measures of
cognitive flexibility and objective behavioral tasks of flexibility, indicating that the measures and tasks may be capturing different dimensions of flexibility (Lounes et al., 2011). In this study, we assessed both cognitive and behavioral flexibility, through both neuropsychological tasks and self-report, examining both general and ED specific flexibility.

**Aims and Hypothesis**

The *a priori* aim and hypotheses of this study were as follows:

**Aim 1:** Assess the association between adaptive vs. maladaptive exercise behaviors and motives and general and eating-disorder specific flexibility.

*Hypothesis 1a:* Task switching errors, an objective marker of inflexibility, are positively associated with exercise dependence.

*Hypothesis 1b:* Task switching errors, an objective marker of inflexibility, are inversely associated with mindful exercise, and positively correlated with exercise rigidity.

*Hypothesis 1c:* Decreased general and eating disorder-specific flexibility are associated with increased exercise dependence.

*Hypothesis 1d:* Decreased general and eating disorder-specific flexibility are associated with decreased mindful and intuitive exercise.

**Methods**

This study was approved by the Institutional Review Board at the University at Albany, State University of New York. Participants reviewed an informed consent form indicating the nature and purpose of the research and confirmed consent to participate prior to completion of questionnaires.

**Participants and Procedures**
Participants were University at Albany undergraduate students who participated in the research in exchange for course credit between February 18, 2020 and September 24, 2020. The consent form emphasized the voluntary and anonymous nature of participation. Inclusion criteria were age 18 years and older and fluency in written English. Participants completed the study on the secure server Qualtrics, in person via computers located in a laboratory on the University at Albany campus prior to April 9, 2020, after which participants completed the study online via a link to the questionnaire that was sent to them by email due to the COVID-19 pandemic and cessation of any in-person research activities on campus.

**Measures**

Participants completed the following questions and measures via the secure server Qualtrics. The Wisconsin Card Sorting Task was administered through the secure PsyTookKit server, with a link to the task embedded into Qualtrics (Stoet, 2010, 2017).

*Demographics.* Participants self-reported age, race, sex, gender identity, sexual orientation, weight, and height (to calculate body mass index).

*Eating Disorder Flexibility Index (EDFLIX).* Flexibility was assessed using the Eating Disorder Flexibility Index, a 36-item scale quantifying both general and eating disorder specific flexibility via ratings on a six-point Likert scale (from 1 = “strongly disagree” to 6 = “strongly agree”). The EDFLIX measures both cognitive inflexibility and aspects of behavioral inflexibility. The scale produces a total score (Cronbach’s $\alpha =.87$ [95% CI: .85, .89] in the present sample) and three subscale scores measuring: general flexibility (e.g., “If I have to, it’s easy for me to change my plans;” Cronbach’s $\alpha =.83$ [95% CI: .80, .86]), ED specific flexibility related to food and exercise (e.g., “I prefer eating the same foods as I usually do;” Cronbach’s $\alpha =.66$ [95% CI: .60, .72]), and ED specific flexibility concerning body shape and weight (e.g., “I
get distressed if I gain weight, no matter what I weigh;” Cronbach’s α = .93 [95% CI: .91, .94]). The EDFLIX was included here to examine the relationship between different motives for exercise and general versus eating- and shape-specific aspects of flexibility.

**Exercise Dependence Scale - 21 (EDS-21).** The Exercise Dependence Scale is a 21-item measure assessing the physiological and psychological aspects of exercise dependence symptoms on a six-point Likert scale (from 1 = “never” to 6 = “always”). Symptoms of exercise dependence captured by the scale are modeled after Diagnostic and Statistical Manual of Mental Health Disorders, 5th edition criteria for substance dependence (American Psychological Association, 2013). The scale operationalizes exercise dependence through seven factors: withdrawal (Cronbach’s α = .84 [95% CI: .81, .87]), continuance (Cronbach’s α = .87 [95% CI: .84, .89]), tolerance (Cronbach’s α = .87 [95% CI: .85, .90]), lack of control (Cronbach’s α = .80 [95% CI: .76, .84]), reduction in other (Cronbach’s α = .75 [95% CI: .70, .80]), time (Cronbach’s α = .88 [95% CI: .85, .90]), and intention effects (Cronbach’s α = .92 [95% CI: .90, .94]). Subscale scores can be used to categorically classify respondents as: at-risk for exercise dependence (scoring a five or six on three or more factors), nondependent-symptomatic (scoring a three or four on three or more factors), or nondependent-asymptomatic (scoring a one or two on four or more factors) (Hausenblas, 2002). Results also produce a total score (Cronbach’s α = .94 [95% CI: .93, .95]), with higher scores indicating more exercise dependence (Ogden et al., 1997).

**Intuitive Exercise Scale (IEXS).** Different ways of approaching exercise were assessed using the IEXS, a 14-item scale measuring four factors: emotional exercise, body trust, exercise rigidity, and mindful exercise. The “emotional exercise” subscale assesses the use of exercise to manage negative emotions (five items; e.g., “I find myself exercising when I am lonely, even
when I do not feel like exercising;” Cronbach’s α = .89 [95% CI: .87, .91]). “Body trust”
captures reliance on internal bodily cues to guide exercise type, frequency, and intensity (three
items; “I trust my body to tell me how much exercise to do;” Cronbach’s α = .80 [95% CI: .75, .83]). “Exercise rigidity” quantifies exercise variety (three items; “I enjoy different types of
physical activities when I exercise;” Cronbach’s α = .83 [95% CI: .80, .86]). “Mindful exercise”
measures awareness of physiological cues to discontinue exercise (three items; “I stop exercising
when I feel pain;” Cronbach’s α = .79 [95% CI: .74, .83]).

Wisconsin Card Sorting Task (WCST). We administered the WCST as an objective
measure of cognitive flexibility. The WCST is a test of cognitive reasoning or set-shifting and
measures how well people can adapt to changing rules. Cards are classified according to different
criteria, with four different ways to classify each card and changes in classification rule every ten
cards. Results from the WCST produce a rate of perseveration errors indicating the number of times
participants continued to apply the old rule, indicating inflexibility.

Statistical Analyses and Power

A total of 579 participants started the study. Participants who did not report their age or
were under the age of 18 (n=57), participants who discontinued the study prior to the beginning
of the exercise questionnaires (n=176), participants who did not report their height or weight
(n=55), and participants whose self-reported height and weight resulted in a BMI less than 10
(n=4) were excluded, resulting in a final sample of n=287 included in the analyses reported here.
Data was not missing nonrandomly (MCAR; Little’s Missing Completely at Random test p>.05)
for all key measures. The main variables of interest were examined for normality; WCST
perseveration errors had a skew of 1.47, no other measures had a skew > |1|. Kurtosis was 2.55
for WCST perseveration errors and < |1| for all other key measures.
Preliminary analyses were run to characterize associations between the main outcome variables and sex, BMI, and sports team membership and determine inclusion as covariates in subsequent tests of our primary hypotheses. Behaviors and attitudes related to exercise, as measured by EDS-21 and IEXS scores, were then examined in relation to indicators of cognitive and behavioral flexibility using General Linear Modeling. Sex, BMI, and sports team membership were initially included as covariates in all analyses but subsequently removed if found to be non-significant; covariates were included in the first step of regression analyses. A one-way analysis of variance (ANCOVA/ANOVA) was used to examine differences in WCST perseveration error scores between EDS-21 groups; Tukey HSD post-hoc analyses were run as indicated (hypothesis 1a). Multiple linear regression was used to examine the relationship between IEXS subscale scores and WCST perseveration scores (hypothesis 1b). We also examined the relationships between EDS-21 and IEXS scores with EDFLIX subscale scores. Multivariate ANOVA was used to assess differences in EDFLIX subscale scores as a function of EDS-21 group membership; follow-up ANOVA’s were run to explore the nature of any significant between-group differences (hypotheses 1c). Multiple linear regression was used to examine the relationship between IEXS and EDFLIX subscale scores (hypotheses 1d).

This study was adequately powered, with minimum samples of $n=159$ for ANOVA (hypothesis 1a), $n=85$ in stepwise regression analyses (hypotheses 1b and 1d), and $n=114$ in MANOVA analysis (hypotheses 1c), assuming power of .80 and alpha of .05.

**Results**

Participants were 62.0% female ($n=178$), with a mean age of 19.23 years ($SD=2.13$); 52.6% of participants identified as white ($n=151$), 24.4% identified as Black ($n=70$), and 84.0%
of participants identified as heterosexual \((n=241)\). Full sample characteristics can be found in Table 1.

There was a significant multivariate main effect of sex on combined IEXS subscale scores \([F(4,280)=5.62, \, p<.001, \, \eta^2=.07]\). Tests of between-subjects effects revealed significant differences in “exercise rigidity” \([F(1,284)=6.20, \, p=.013, \, \eta^2=.02]\) and “mindful exercise” \([F(1,284)=16.47, \, p<.001, \, \eta^2=.06]\) subscales scores, with women scoring lower on “exercise rigidity” and higher on “mindful exercise”. There was also a significant multivariate main effect of sex on combined EDFLIX subscale scores \([F(3,283)=12.89, \, p<.001, \, \eta^2=.12]\). Tests of between-subjects effects revealed significant differences in “General” \([F(1,286)=11.59, \, p=.001, \, \eta^2=.04]\) and “Weight & Shape” \([F(1,286)=31.69, \, p<.001, \, \eta^2=.10]\) flexibility subscales scores, with women scoring lower on both. Furthermore, there was a significant difference in EDFLIX total score \([t(285)=-4.08, \, p<.001]\), with women scoring significantly lower. There was also a significant difference in EDS-21 total score by sex, \([t(276)=-3.58, \, p=.01]\), with females scoring significantly lower. Lastly, a chi-square test of independence showed a significant relationship between sex and EDS-21 group \([\chi^2(2, \, n=278) = 7.56, \, p=.02]\).

Multivariate main effect of sports team on combined IEXS subscale scores was non-significant \((p>.05)\). Multivariate main effect of sports team on combined EDFLIX subscale scores was also non-significant \((p>.05)\). T-test yielded significant differences in EDS-21 total score \([t(275)=2.01, \, p<.05]\), with participants who reported being on a sports team scoring significantly higher. Multivariate main effect of sports team on combined EDFLIX subscale scores was non-significant \((p>.05)\). Lastly, a chi-square test of independence showed a no significant relationship between sport team membership and EDS-21 group \([p>.05]\). BMI was
significantly correlated with IEXS “body trust” subscale scores \((p=.04)\), and EDFLIX “Weight & Shape” subscale scores \((p=.02)\).

**Hypothesis 1a:** A one-way analysis of variance, comparing WCST perseveration errors by EDS-21 category was significant \([F(2, 250)= 4.38, p = .01]\). Tukey’s HSD post-hoc analyses revealed significant differences between the “at risk for dependence” group, which made on average significantly more errors, compared to the “nondependent symptomatic” and the “nondependent asymptomatic” groups (post-hoc \(p = .01\) and \(.02\), respectively) (see Table 2 for means and standard deviations).

**Hypothesis 1b:** A multiple linear regression was conducted to examine the amount of variance in WCST perseveration errors accounted for by IEXS subscale scores, beyond that accounted for by the covariates. The first step of the model, with sex, BMI, and sports team membership as the predictor variables was non-significant \([F(3,255)=2.03, p =.11, R^2 =.02]\). Addition of IEXS subscale scores as predictor variables in the second step of the model did not result in a statistically significant increase in variance of WCST scores accounted for and the model remained non-significant \([F(7,251)=1.36, p =.23, R^2 =.04]\) (see Table 3).

**Hypothesis 1c:** There was a significant multivariate main effect of EDS-21 group on combined EDFLIX subscale scores \([F(6, 542) = 6.55, \text{Wilks’ } \lambda = .87, p< .001, \eta^2_p = .07]\), with BMI and sex as significant covariates \((p < .01\) and \(.001\), respectively). Tests of between-subjects effects revealed significant group differences in scores on the “Food & Exercise” \([F(2, 273) = 17.89, p< .001, \eta^2_p = .12]\) and “Weight & Shape” subscales \([F(2, 273) = 6.64, p < .01, \eta^2_p = .05]\). Follow-up ANOVAs revealed significant differences between the “nondependent asymptomatic” group and the “at risk for dependence” group and the “nondependent symptomatic” groups on
the “Food & Exercise” subscale (both post-hoc $p<.001$). Follow up analyses revealed no significant difference on the “Weight & Shape” subscale by EDS group (all $p > .05$).

_Hypothesis 1d:_ Multiple linear regression was conducted to examine the amount of variance in EDFLIX global scores accounted for by IEXS subscale scores, beyond that accounted for by the covariates. In the first step of the model, sex, BMI, and sports team membership were entered as predictor variables, and were significantly related to EDFLIX global score [$F(3,280)=5.42, p = .001, R^2 = .055$]. Addition of IEXS subscales as predictor variables in the second step of the model resulted in a significant increase in the amount of variance in EDFLIX global score accounted for ($R^2$ change for model 2 = .133 $p < .001$) [$F(7,276)=9.12, p < .001, R^2 = .188$] with “emotional exercise”, “mindful exercise” and “body trust” subscales as significant predictors and sex as a significant covariate ($p<.001$) (see Table 4).

**Discussion**

Research to date has shown maladaptive exercise is frequently linked with EDs, as a precursor to or maintaining factor of maladaptive eating behaviors (Bamber et al., 2000; Cook et al., 2014; Smolak et al., 2000). Cognitive and behavioral inflexibility is a transdiagnostic factor proposed to contribute to the high comorbidity of these behaviors. This study examined how different motives for and relationships with exercise are differentially associated with cognitive and behavioral inflexibility, a marker of EDs. Results from this study suggests greater flexibility in those endorsing “intuitive exercise”, and decreased flexibility in those endorsing “rigid exercise” and exercise dependence. Findings are thus consistent with the view of cognitive and behavioral inflexibility as a transdiagnostic factor underpinning both maladaptive exercise and eating behaviors.
Results support our hypothesis that exercise dependence is associated with decreased flexibility on set-shifting tasks. Specifically, individuals categorized as “at risk for exercise dependence” exhibited significantly lower flexibility than those not “at risk” for exercise dependence, even when exhibiting some symptoms. To the extent that exercise dependence is causally involved in the maintenance of ED pathology, targeting inflexibility in exercise may therefore curtail maladaptive physical activity as well as alleviate ED symptomology. However, set-shifting performance was not associated with differences on the IEXS, including rigid or mindful approaches to exercise. It is possible that the WCST did not capture the dimensions of inflexibility associated with less severe exercise behaviors and attitudes reported on the IEXS compared to more extreme exercise dependence reported on the EDS-21.

While the WCST task, capturing objective flexibility, was not associated IEXS scores, self-reported EDFLIX subscale scores were associated with IEXS scores. The EDFLIX, in contrast to the WCST, assesses both cognitive and behavioral flexibility, and captures dimensions of flexibility related to both eating behaviors and attitudes and everyday flexibility (Dahlgren et al., 2019). Therefore, our results that ED-specific and general flexibility but not set-shifting performance were associated with IEXS scores indicates value in utilizing the EDFLIX to assess flexibility. Increased “Global Flexibility” was found to be associated with increased “mindful exercise” and “body trust” (listening to one’s bodily cues to signal exercise) but was associated with decreased “emotional exercise”. Importantly, while BMI, sex, and sports team membership are significantly associated with inflexibility, the IEXS subscales accounted for significantly more of the variance, totaling 18.8%. These results indicate that maladaptive exercise motives and relationships, including less mindful and more rigid exercise are associated with inflexibility, emphasizing clinical value in cultivating more flexible relationships with
exercise to decrease risk of problematic exercise behaviors. Furthermore, results showed that exercise dependence is associated with decreased “Food & Exercise” and “Weight & Shape” flexibility, suggesting ED specific inflexibility is associated with exercise dependence as well. Specifically, individuals “at risk for exercise dependence” and individuals not at risk but exhibiting symptoms of exercise dependence reported significantly lower “Food & Exercise” related flexibility compared to the “nondependent asymptomatic” group.

Clinical practice and research have shown that individuals with EDs are not only rigid about food, but about exercise, and other everyday tasks as well (Dahlgren et al., 2019). However, while the cooccurrence of maladaptive exercise and ED risk is well established, the mechanisms underpinning this relationship are nuanced. Elucidating cognitive and behavioral flexibility as a transdiagnostic mechanism in this study helps shed light on possible interventions for eating pathology and problematic exercise, including at subclinical levels. Research suggests that targeting flexibility outside of eating-related behaviors may work to increase flexibility transdiagnostically. A 2014 review of 45 papers including four randomized control trials, examining the effectiveness of cognitive remediation therapy (CRT), a therapy targeting inflexibility outside of eating-related behaviors, for Anorexia Nervosa, concluded that CRT both enhances treatment effectiveness and increases cognitive flexibility (Dahlgren & Ro, 2014). Furthermore, a study exploring the impact of CRT in EDs found that CRT significantly improved neurocognitive functioning, including flexibility, assessed through a set-shifting neuropsychological task and self-report measure of flexibility (Leppenen et al., 2018).

Flexibility in exercise may be another important point of intervention for increasing flexibility to indirectly impact eating-related pathology. To date, it appears there are no studies examining CRT specifically aimed at exercise; future work should consider adapting CRT to focus on
enhancing flexibility in exercise specifically. Research has also suggested benefit in helping individuals cultivate positive motivations for behavior. Specifically, studies have suggested that providing rational for intrinsic motivations and encouraging autonomy may cultivate more adaptive exercise motives (Weman-Josefsson et al., 2017). Prior research indicates that adaptive motives for exercise are associated with more mindful exercise, and results from the current study show a positive relationship between mindful exercise and flexibility, thus establish more positive motives for exercise may in turn increase flexibility (Ramsey, 2018).

There are several strengths to this study. First, this study surveyed a large, demographically diverse sample comprised of young adults, who are at the highest risk of developing EDs, allowing us to speak to issues relevant to the group most at-risk for developing eating pathology (Galmiche et al., 2019). Second, while there are a wide range of measures capturing exercise behaviors, this study utilized well-validated measures evaluating exercise motivations and behaviors. Furthermore, this study included both objective and subjective measures of flexibility. Findings from this study indicate that the WCST and EDFLIX appear to measure different dimensions of flexibility, strengthening the likelihood that all aspects of inflexibility were captured in this study, increasing support for the implications of this study. Despite the strengths of this study, there are several limitations, and findings should be considered in the context of these limitations. First, the study sample consisted of undergraduate students, generating a subclinical sample, with an “at-risk for exercise dependence” group of \( n=12 \), limiting the generalizability of findings to more severe populations. Second, this research was cross-sectional in design, and it is important to consider the relationships investigated may be bidirectional; for example, exercise dependence may promote psychological inflexibility, and psychological inflexibility may be an etiological mechanism for exercise dependence. Third,
neuropsychological tasks including the WCST require use of multiple domains of cognitive function, therefore we cannot elucidate inflexibility as the sole mechanism involved. Future studies should aim to examine inflexibility between different sports as well as different sport levels or athletic performance. Future studies should also aim to elucidate differences in associations between inflexibility in exercise and different EDs. Studies have shown executive function differences between EDs, including Anorexia Nervosa, Bulimia Nervosa, and Binge Eating Disorder. Lastly, future studies should begin to examine clinical utility in targeting flexibility in exercise.

Findings suggest greater general and ED specific flexibility in those endorsing more adaptive and intuitive behaviors and attitudes around exercise, and lower flexibility around exercise, food, weight, and shape in those endorsing more rigid and dependent exercise behaviors. Elucidating inflexibility in exercise as a potential point of intervention and prevention is efficacious given the high prevalence rates of maladaptive exercise in EDs, difficulty of treating EDs, and high rates of mortality. Adapting training structures to minimize rigidity around exercise and promoting adaptive, intrinsic motives for exercise may be beneficial steps at subclinical levels. Clinicians may consider targeting inflexibility in exercise through CRT as an adjunct.
Table 1

*Participant Demographics*

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Table 2

*EDS-21 Group Performance on WCST*

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<tr>
<td>Nondependent-</td>
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<tr>
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Table 3
Multiple linear regression model estimating associations between WCST perseveration errors (pe), IEXS subscale scores, and covariates.

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<th>Body trust</th>
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*p < 0.05, **p < 0.01, ***p ≤ 0.001.
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<td>-.182***, -.219***</td>
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<td>.07, -.14, 4.77</td>
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*p < 0.05, **p < 0.01, ***p ≤ 0.001.
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