Emotion regulation and executive functioning: a comparison of collegiate taekwondo athletes, other athletes, and non-athletes

Rae Danett Drach
University at Albany, State University of New York, rae.drach@gmail.com

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EMOTION REGULATION AND EXECUTIVE FUNCTIONING: A COMPARISON OF COLLEGIATE TAEKWONDO ATHLETES, OTHER ATHLETES, AND NON-ATHLETES

by

Rae Danett Drach

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Abstract

Emotion regulation and executive functioning are intricate processes that allow individuals to initiate, inhibit, or modulate emotions and behaviors in service of personally-relevant goals in familiar, novel, and ambiguous contexts. Research has demonstrated that exercise improves emotion regulation and executive functioning. Recently, researchers have started investigating whether mindful exercise – physical exercise that incorporates an inwardly directed, non-judgmental, contemplative focus – explicitly strengthens these capabilities. As a martial art and sport that combines training in body movement and mental focus, taekwondo is a globally popular example of mindful exercise that may benefit affective and cognitive processes. The current study examined whether taekwondo uniquely promotes adaptive emotion regulation and executive functioning by examining differences in self-report questionnaires and behavioral task performance among collegiate taekwondo practitioners (n = 63), non-taekwondo athletes (n = 96), and non-athletes (n = 159). Findings support overall emotion regulation benefits of athletic engagement, as well as specific emotion regulation and executive functioning benefits of taekwondo. Compared to non-athletes, both taekwondo and non-taekwondo athletes endorsed better access to emotion regulation strategies, better emotional clarity, and less recent experience of depression and anxiety symptoms. Moreover, compared to the other two groups, taekwondo athletes performed better on working memory and cognitive flexibility tasks and endorsed greater cognitive flexibility, less use of catastrophizing, and fewer impulse control difficulties. Hence, engagement in taekwondo was related to several benefits beyond that of athletic engagement more broadly. Limitations and future directions are discussed.

Keywords: taekwondo, exercise, emotion regulation, executive functioning
Table of Contents

Acknowledgements...........................................................................................................ii

Abstract............................................................................................................................iii

Table of Contents..............................................................................................................iv

Introduction.......................................................................................................................1

Emotion Regulation.......................................................................................................2

Emotion Regulation and Executive Functioning...........................................................12

Improving Emotion Regulation and Executive Functioning Via Exercise.....................23

Mindful Exercise, Emotion Regulation, and Executive Functioning..................................30

Potential Benefits of Taekwondo.....................................................................................31

Sports Participation in the Context of a Global Pandemic.................................................34

The Current Study..........................................................................................................35

Methods...........................................................................................................................37

Participants....................................................................................................................37

Procedures.....................................................................................................................37

Measures.........................................................................................................................38

Statistical Power and Analyses.......................................................................................45

Results.............................................................................................................................49

Demographic Characteristics.........................................................................................49

Correlation Analyses Among Variables of Interest.........................................................51

Differences in Emotion Regulation, Dysregulation, Depression, Anxiety, and Stress.......55

Differences in Executive Functioning.............................................................................57
Emotion Regulation and Executive Functioning: A Comparison of Collegiate Taekwondo Athletes, Other Athletes, and Non-athletes

Introduction

Emotion regulation and executive functioning are critical contributors to daily educational, occupational, and social performance, as well as long-term well-being. Emotion regulation allows individuals to modulate emotions in service of personally-relevant goals (Thompson, 1994; Thompson & Gross, 2007), and executive functions enable adaptive responses to novel or ambiguous situations (Zelazo & Carlson, 2012). In a world with nuanced, ever-changing stimuli and expectations, such flexible response capacity is essential. Fortunately, research has shown that emotion regulation and executive functioning are malleable processes that can be strengthened. Interventions such as goal management training (Tornas et al., 2016), cognitive skills training (e.g., gaze pattern and working memory training; Wadlinger & Isaacowitz, 2011; Xiu et al., 2018), and the practice of mindfulness and related techniques (e.g., meditation and yoga; Gallant et al., 2016; Lam & Seiden, 2020; Menezes et al., 2105; Roemer et al., 2015) have shown some efficacy in enhancing these processes. Exercise, particularly exercise which incorporates mindfulness and self-control, may be one method to promote adaptive emotion regulation and executive functioning. Taekwondo, a mindful martial art and sport that combines training in body movement and mental focus in service of self-defense, may be one type of exercise particularly suited to strengthening these capabilities. To investigate this possibility, this study compares self-report measures and behavioral indices of emotion regulation and executive functioning in groups of college student taekwondo athletes, non-taekwondo athletes, and non-athletes.
Emotion Regulation

Emotion regulation refers to the complex psychological processes by which individuals recognize and modulate their emotions. According to Thompson (1994), emotion regulation consists of extrinsic and intrinsic processes involved in initiating, maintaining, and modulating the occurrence, intensity, and expression of emotions. More recent definitions explicitly acknowledge the functionality of emotion regulation in utilizing emotion-modifying behaviors to achieve individual goals and/or promote social adaptation (Eisenberg et al., 2006; Thompson, 1994; Thompson & Gross, 2007).

Theories of Emotion Regulation

Emotion regulation involves the maintenance, enhancement, inhibition, or subdual of emotional arousal (Thompson, 1994). At times, individuals may benefit from maintaining an emotionally aroused state, such as when responding to an emergency situation. At other times, they may benefit from up-regulating (e.g., increasing excitement in preparation for a competition) or down-regulating (e.g., decreasing anger in advance of an important conversation) specific emotions. Additionally, emotion regulation may influence the discrete emotion experienced, its intensity, its timing, and/or its duration (Thompson, 1994). Whereas emotion regulation is often discussed with regard to “negative” or unpleasant emotions, it also influences the experience of “positive” or pleasant emotions.

Early conceptualizations of emotion regulation equated effective regulation to control or reduction of emotional experience and expression, with the goal of diminishing negative affect and physiological arousal (Kopp, 1989; Zeman & Garber, 1996). However, attempts to control, inhibit, or avoid emotional experience and expression have since been shown to lead to paradoxical dysregulation. For instance, in an early study on physiological responses to stress,
participants with a tendency to constrict emotional expression (e.g., exhibit less facial response to a shock stimulus) demonstrated increased physiological arousal compared to participants who were more emotionally expressive (Notarius & Levenson, 1979). Similarly, in another study, experimenters explicitly instructed one group of participants to suppress their emotional expressions while watching sad, neutral, and amusing films. The suppression group, compared to a control group, demonstrated increased physiological reactivity to both the sad and neutral films (Gross & Levenson, 1997). As high levels of physiological arousal are more difficult to regulate, these findings suggest that attempts to control emotional expression may paradoxically increase risk for dysregulation and may underlie many psychological disorders (Hayes et al., 1996). Some theorists continue to focus specifically on hedonic emotion regulation, or maximizing positive, desired emotions and minimizing negative, unwanted emotions. However, this conceptualization disregards the above findings and fails to consider instrumental, goal-oriented motives of emotion regulation.

Another conceptualization of emotion regulation suggests that regulation is indistinguishable from emotion (Campos et al., 2004). In this unitary model, both emotion generation and emotion regulation occur in parallel and are hypothesized to serve the same functions. For instance, appraisal of a situation is responsible for both activating and regulating emotions (Campos et al., 2004). This conceptualization has not gained significant traction in the field, and the majority of researchers agree that emotion generation and regulation are separate phenomena (Kobylnska & Kusev, 2019).

In his seminal process model of emotion regulation, Gross (1998, 2015) proposed that there are four steps involved in generating emotions and five points in this generative process where emotion regulation can occur. To generate emotions, an individual: 1) perceives stimuli
(e.g., thoughts, feelings, sensations, external cues) in their current situational context, 2) attends to the stimuli or their attributes, 3) appraises the stimuli’s significance as it relates to their current wants, needs, or goals, and 4) translates this appraisal into changes in experience, expressive behavior, and autonomic response. To regulate emotions, one can use the following five classes of strategies at specific time points in the emotion generative sequence: situation selection, situation modification, attentional deployment, cognitive change, and response modulation (Gross, 1998, 2015). This model specifically emphasizes cognitive and behavioral control of emotion (Ochsner et al., 2012). Situation selection involves keeping oneself away from stimuli that elicit unwanted emotions and seeking out stimuli that elicit desired emotions. Situation modification occurs when an individual finds themselves in the presence of stimuli that elicit unwanted emotions and changes something about the situation to alter its impact. Attentional deployment uses selective attention (i.e., moving the focus of attention towards or away from stimuli) and distraction (i.e., limiting attention to an external stimulus by focusing internally on information maintained in working memory) to control what stimuli are selected into or out of the emotion generative process. Cognitive change involves changing the way one appraises the meaning of stimuli (e.g., cognitive reappraisal). And, finally, response modulation targets how emotions are expressed through behavior (e.g., suppression). The first four classes of strategies are antecedent-focused because they are employed before an emotional response, whereas response modulation strategies are response-focused, or employed after an emotional response (Gross, 1998, 2015; Ochsner et al., 2012). Antecedent-focused strategies, such as cognitive reappraisal, are generally considered more effective than response-focused strategies, such as suppression (Gross & John, 2003; Kobylinska & Kusev, 2019).
Most recent emotion regulation models contend that emotions, both pleasant and unpleasant, serve functional purposes. Moreover, these models postulate that adaptive emotion regulation involves appropriately *modulating*, not necessarily inhibiting, the experience of emotions (Eisenberg et al., 2006; Thompson, 1994; Thompson & Gross, 2007). In other words, rather than changing the discrete emotion itself, adaptive regulation alters the intensity, timing, and/or duration of emotional experience to meet current contextual demands. This alteration modulates arousal to reduce urgency and improve behavioral control to act in accordance with individual goals (Gratz & Roemer, 2004; Linehan, 1993). These goals can be implicit and outside conscious awareness or explicit and accessible to awareness; research generally focuses on the latter (Ochsner et al., 2012).

Researchers often investigate specific regulation strategies that individuals use to modulate emotions and their effectiveness. For instance, Garnefski et al. (2001) delineate the following nine cognitive emotion regulation strategies based on the premise that cognitive processes help people regulate their affective experience: self-blame (thinking oneself is at fault), acceptance (awareness and resignation), rumination (repetitive thinking), positive refocusing (switching attention to more pleasant topics), refocus on planning (laying out steps to take), positive reappraisal (reframing with a positive interpretation), putting into perspective (comparing situations appropriately), catastrophizing (emphasizing the negatives), and other-blame (thinking that others are at fault). Self-blame, rumination, catastrophizing, and other-blame are generally considered maladaptive, whereas acceptance, positive refocusing, refocus on planning, positive reappraisal, and putting into perspective are generally considered adaptive strategies (Garnefski et al., 2001). Other specific oft-studied strategies include problem-solving (conscious attempts to change a situation or its consequences), cognitive reappraisal (attempts to
reconsider, reframe, or gain new perspectives), suppression (attempts to inhibit unwanted psychological experiences or expressive responses), and avoidance (attempts to evade experiential or behavioral situations). Suppression and avoidance are often seen as maladaptive and associated with negative outcomes, whereas cognitive reappraisal and problem-solving are generally considered adaptive and associated with more positive outcomes.

However, context matters. For instance, suppression has generally been associated with negative social consequences and poorer psychological functioning (Gross & John, 2003), but this may be moderated by cultural values. To illustrate, Butler et al. (2007) found that for participants holding Western individualist values, compared to those holding Eastern collectivist values, experimentally-induced suppression led to a greater reduction in interpersonal responsiveness, more negative partner perception, and more hostile behavior in a randomly-paired face-to-face interaction paradigm. As another example, cognitive reappraisal, thought to be largely effective, appears to work best when the situation inducing the emotion is not controllable (Troy et al., 2013). In situations that are controllable, elicit strong emotional responses, or induce time constraints, other strategies such as distraction or problem-solving may be more effective (McRae, 2016; Troy et al., 2013). Recent finding even suggest that reappraisal is less effective for people who experience chronically low levels of situational control, such as those from low socioeconomic status backgrounds (Troy et al., 2017).

Importantly, recent models of adaptive emotion regulation emphasize not only access to a range of emotion regulation strategies but also the flexible use of different strategies depending on current situational demands (Aldao & Nolen-Hoeksema, 2012; Gratz & Roemer, 2004). Aldao and Nolen-Hoeksema (2012) investigated a contextual model of emotion regulation by asking participants to retroactively describe eight emotion-eliciting situations and rate the extent
to which they implemented specific strategies (e.g., acceptance, problem-solving, reappraisal, avoidance, self-criticism, hiding expression, suppression of experience, worry/rumination) to regulate their affect. They found that participants implemented putatively adaptive strategies, compared to maladaptive strategies, with more variability across situations. Furthermore, variability of acceptance and problem-solving predicted lower levels of psychopathology, suggesting flexible strategy implementation is associated with better mental health (Aldao & Nolen-Hoeksema, 2012). Additionally, Bonanno et al., (2004) investigated flexibility effectiveness by instructing participants to enhance emotional expression, suppress emotional expression, or behave normally on different trials of a laboratory task. Flexibility, or the ability to both enhance and suppress the expression of emotions, was related to better adjustment in a follow-up approximately two years later (Bonanno et al., 2004). In a previously mentioned study, Troy et al. (2013) found that cognitive reappraisal ability was associated with lower levels of depression only for participants experiencing uncontrollable stressful situations and was actually associated with greater levels of depression for those experiencing controllable stressful situations. Similarly, Haines et al. (2016) found that participants with relatively high well-being used reappraisal more in situations they perceived as less controllable, compared to those they perceived as more controllable, highlighting the benefit of using strategies flexibly under different conditions. Conceptual models have also suggested effective emotion regulation is an interaction not only of strategy and situation, but also of person-specific variables, such as gender, age, and personality (Dore et al., 2016; Kobylnska & Kusev, 2019).

In short, emotion regulation involves the following: 1) awareness and understanding of emotions, 2) acceptance of emotions, 3) capability to control impulsive behaviors and engage in goal-directed behaviors, and 4) flexible use of situationally appropriate strategies to meet
individual goals and contextual demands. Emotion dysregulation occurs in the absence of any or all of these abilities (Gratz & Roemer, 2004).

**Role of Emotion Regulation in Psychopathology**

Research suggests that emotion dysregulation plays a transdiagnostic role in a range of maladaptive behaviors and psychopathologies (Aldao et al., 2016; Beauchaine & Cicchetti, 2019; Gross & Munoz, 1995. Dysregulation may occur from a lack of access to emotion regulation strategies, underuse of putatively adaptive strategies, overuse of putatively maladaptive strategies, or breakdowns in the ability to flexibly switch among strategies based on contextual demands. Dysregulation can be measured by observational and experimental studies, as well as by self-report measures, such as the Difficulties in Emotion Regulation Scale, which quantifies difficulties with awareness and understanding of emotions, acceptance of emotions, engagement in goal-directed behaviors, and access to effective emotion regulation strategies (Gratz & Roemer, 2004).

Deficits in emotion regulation are prominent in depressive and anxiety disorders. In fact, some clinical features of depressive and anxiety disorders, such as rumination, avoidance, and excessive worry, can be conceptualized as maladaptive attempts at emotion regulation (Campbell-Sills & Barlow, 2007). Specifically, studies have shown rumination and suppression are associated with depressive symptoms across genders and age groups (Nolen-Hoeksema & Aldao, 2011). Moreover, patients with major depressive disorder engage in greater suppression of both positive and negative emotions than healthy controls (Beblo et al., 2012). Garnefski and Kraaij (2006) compared the use of cognitive emotion regulation strategies and symptoms of depression in five different samples (i.e., early adolescent, late adolescent, adult, older adult, and psychiatric adult). In all samples, use of acceptance, rumination, and catastrophizing strategies
were positively correlated with depressive symptoms. In all groups, except the older adults, self-blame and other-blame were also positively correlated with depressive symptoms. Moreover, multiple regression analyses revealed that greater use of rumination, catastrophizing, and self-blame predicted greater depressive symptomatology, and greater use of positive reappraisal predicted less depressive symptomatology (Garnefski & Kraaij, 2006).

With regard to studies of emotion dysregulation and anxiety, Craske et al., (1990) found that participants who reported high levels of agoraphobic avoidance after an initial panic attack were more likely to develop subsequent anxiety disorders, compared to those who reported low levels of avoidance. Campbell-Sills et al. (2005) found that participants with a mood or anxiety disorder reported less acceptance of their emotions and more suppression than a nonclinical control group. Additionally, when these participants watched a negative emotion eliciting film, clinical participants used suppression more and exhibited higher heart rate than controls (Campbell-Sills et al., 2005). In a proposed emotion dysregulation model of anxiety, Mennin et al. (2004) suggest that generalized anxiety disorder involves experiencing emotions quickly, easily, and intensely, making emotion regulation difficult. Supporting this model, researchers found that deficits in emotional clarity, the acceptance of emotions, the ability to engage in goal-directed behaviors when distressed, and access to effective regulation strategies were all significantly related to worry and analogue generalized anxiety disorder status beyond the contribution to variance of negative affectivity (Salters-Pedneault et al., 2006). An integrative review of emotion regulation and anxiety disorders found that maladaptive emotion regulation strategies characterize individuals with anxiety disorders and that emotion dysregulation is significantly related to anxiety disorder symptoms, even when controlling for emotional reactivity constructs (Cisler et al., 2010).
Finally, a meta-analytic review of 114 studies examined the relationships between emotion-regulation strategies (i.e., acceptance, avoidance, problem-solving, reappraisal, rumination, and suppression) and four psychopathologies (i.e., anxiety, depression, eating, and substance-related disorders). This review found the following effect sizes across disorders: large for rumination (positive association); medium to large for avoidance (positive association), problem-solving (negative association), and suppression (positive association); and small-to-medium for reappraisal (negative association) and acceptance (negative, non-significant association). In this review, anxiety and depression disorders were most consistently associated with emotion regulation strategies (Aldao et al., 2010), but comprehensive evidence also supports the role of emotion dysregulation in eating disorders, personality disorders, bipolar disorders, trauma-related disorders, substance-use disorders, attention-deficit/hyperactivity disorder, and conduct-related disorders (Barkley, 2015; Beauchaine et al., 2007; Berking et al., 2011; Ehring & Quack, 2010; Garofalo et al., 2018; Green et al., 2011; Gross & Muñoz, 1995; Harrison et al., 2010; Linehan, 1993; Weiss et al., 2013; Wilcox et al., 2016). An in-depth review of these disorders is outside the scope of this study.

**Neural Substrates Underlying Emotion Regulation**

Intricate and distributed cortical and subcortical neural systems govern the set of complex processes of emotion regulation. The following is a brief summary of major findings from functional magnetic resonance imaging studies on emotion generation and regulation; for more detailed information, see comprehensive reviews and meta-analyses on the topic (Etkin et al., 2015; Frank et al., 2014; Kohn et al., 2014; Ochsner et al., 2012).

Emotion generation involves the amygdala, ventral striatum, anterior insula, dorsal-anterior cingulate cortex, and periaqueductal gray. The amygdala is involved in the perception
and encoding of arousing goal-relevant stimuli, such as expressions of fear which may convey the presence of potential threats (Cunningham et al., 2008; Whalen et al., 2004). The ventral striatum is involved in learning which cues predict reinforcing outcomes (Pagnoni et al., 2002). The insula is involved in processing viscerosensory inputs from the body, with the anterior region in particular associated with interoceptive awareness of the body in affective states with a strong visceral component (e.g., disgust; Critchley et al., 2004). The role of the dorsolateral anterior cingulate cortex in emotion generation is somewhat controversial but appears to be involved in appraisal, monitoring of somatic states, and the generation of physiological and behavioral responses (Etkin et al, 2015). Finally, the deeper midbrain periaqueductal gray has often been implicated in animal studies and has been shown to drive early physiological responses to emotional experiences in humans (Buhle et al., 2013).

Emotion regulation appears driven primarily by frontal networks (Frank et al., 2014). Specifically, brain regions involved in explicit, top-down emotion regulation (i.e., cognitive control of emotion) include the dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, pre-supplementary motor area, and supplementary motor area. The dorsolateral prefrontal cortex is associated with decision-making and inhibiting prepotent responses, including those related to affective material, and the ventrolateral prefrontal cortex is associated with goal-relevant response selection and inhibition (Etkin et al., 2015). Recently, transcranial direct current stimulation applied over the ventrolateral prefrontal cortex was shown to modulate perception of fear and anxiety (Vergallito et al., 2018). The supplementary and presupplementary motor areas are involved in the planning and execution of behavioral regulation responses (Kohn et al., 2014). Furthermore, the ventral-anterior cingulate cortex and ventromedial prefrontal cortex
appear to be involved in implicit emotion regulation, or the processing and modulation of stimuli which occurs outside of conscious awareness (Etkin et al., 2015).

**Emotion Regulation and Executive Functioning**

Adaptive emotion regulation relies heavily on executive functioning. Executive functions are top-down neurocognitive processes involved in the conscious, goal-directed control of thought, action, and emotion that enable adaptive responses to novel or ambiguous situations (Zelazo & Carlson, 2012). Whereas the literature contains terminological inconsistencies, researchers generally agree there are three core executive functions: inhibitory control (i.e., self-regulation or withholding prepotent responses), working memory (i.e., mentally maintaining and manipulating information), and cognitive flexibility (i.e., set shifting and adapting behavior to meet situational demands; Diamond, 2013; Miyake et al., 2000). Researchers who prefer the term “cognitive control” to executive functions often use the nomenclature “inhibiting”, “updating”, and “shifting” to refer to the processes of inhibitory control, working memory, and cognitive flexibility, respectively (Pruessner et al., 2020). These core executive functions lay the foundation for higher-order executive functions, such as reasoning, problem solving, and planning (Diamond, 2013). Research generally supports the role of these three core executive functions in regulating emotions.

**Inhibitory Control**

Emotion regulation emphasizes the ability to inhibit inappropriate, impulsive, or undesirable behaviors. Inhibitory control is the capacity to voluntarily inhibit or regulate strong or automatic behavioral or attentional responses (Logan & Cowan, 1984; Davis et al., 2003; Durston et al., 2002). In other words, inhibitory control allows an individual to override compulsive or dominant behavioral tendencies (e.g., refrain from reading and responding to a
text message while driving) and focus on relevant stimuli in the presence of irrelevant stimuli (e.g., ignore classroom distractions to attend to a teacher’s instructions). In this way, inhibitory control includes both behavioral and cognitive components. In reference to emotion regulation, inhibitory control may enable individuals to override initial or default emotional responses and regulatory strategies (Schmeichel & Tang, 2015).

Emotion-relevant information often receives priority in cognitive processing; however, this is not always done in an efficient or goal-oriented manner (Bartholomew et al., 2019). Inhibitory control helps direct attention and behavior towards relevant stimuli and away from irrelevant stimuli to down-regulate, maintain, or up-regulate emotions to achieve context-specific goals (Logan & Cowan, 1984; Davis et al., 2003; Durston et al., 2002). Consider inhibitory control’s role in two emotion regulation strategies: reappraisal and suppression (Gross & Levenson, 1997; Joormann & Gotlib, 2010). To reappraise a situation, a person must regulate an initial emotional reaction in a top-down manner to direct attention to other situational components. They may not dismiss the initial response, but they can also consider alternative interpretations. Inhibitory control is the cognitive process that allows someone to modulate an initial appraisal in an adaptive way (Joormann & Gotlib, 2010). In contrast, suppression is essentially the reduction of emotional experience and expression. Suppression comes later in the emotion-generative response than reappraisal and primarily modifies the behavioral aspect of the emotion response, without actually reducing the subjective and physiological experience of negative emotion (Cutuli, 2014). Bottom-up behavioral control may play a stronger role in suppression than top-down cognitive control.

Importantly, emotion regulation strategies that focus on cognitive change, such as reappraisal, consistently appear more effective than those that focus on cognitive avoidance, such
as suppression (Gross & John, 2003; Joormann & Gotlib, 2010). Across a sample of depressed and never-depressed participants, Joormann and Gotlib (2010) found that reduced inhibition of negative material was related to less use of reappraisal and greater use of suppression. Within the depressed participants, reduced inhibitory control was also associated with greater use of rumination (Joormann & Gotlib, 2010). Similarly, De Lissnyder et al. (2011) found that high ruminators, compared to low ruminators, displayed slower latencies on an inhibition task. However, some study results are more equivocal and do not support a fundamental relationship between inhibitory control and the use of rumination, reappraisal, and/or suppression (Aker et al., 2014; Hendricks & Buchanan, 2016; McRae et al., 2012; Sperduti et al., 2017).

**Working Memory**

In addition to inhibitory control, working memory likely plays an important role in emotion regulation. Working memory is the ability to maintain and manipulate information over a short period of time in service of a particular goal (Baddeley, 1992; Baddeley, 2012). For instance, an individual uses working memory to hold an address in mind while also encoding directions for how to get there. Working memory may underlie emotion regulation by enabling the storage and modification of both conceptual and perceptual information, especially that which is emotionally-relevant.

Many recent studies support a link between working memory and emotion regulation. Schmeichel et al. (2008) examined individual differences in working memory and emotion regulation by asking participants to suppress negative and positive emotions and to unemotionally appraise emotional stimuli. Participants with better working memory were better able to accomplish these tasks. In another study, the same group of researchers also found that better working memory was associated with more spontaneous emotion regulation, as reflected
by greater self-enhancement and reduced negative affect following negative feedback (Schmeichel & Demaree, 2010). In general, studies have shown that greater working memory ability is associated with increased and/or more successful implementation of both reappraisal and expressive suppression (Hendricks & Buchanan, 2016; McRae et al., 2012; Schmeichel et al., 2008; Schmeichel & Demaree, 2010; Sperduti et al., 2017). Notably, the ability to update emotional information in working memory may moderate the efficacy of certain cognitive emotion regulation strategies. Specifically, high emotional working memory capacity, compared to low working memory capacity, appears to be associated with less experience of negative emotions after reappraisal and rumination (Pe et al., 2013). Studies of working memory training paradigms have also demonstrated some success at reducing use of maladaptive strategies (e.g., rumination) though not at increasing use of adaptive strategies (e.g., cognitive reappraisal; Hoorelbeke et al., 2016; Siegel et al., 2007).

Notably, working memory supports inhibitory control, and inhibitory control supports working memory (Diamond, 2013). For instance, an individual must hold a goal in mind to determine what information is relevant and what information or responses to inhibit. On the other hand, to relate multiple ideas and recombine them in new ways, an individual must resist internal (e.g., old thought patterns) and external (e.g., irrelevant information) distractions.

**Cognitive Flexibility**

Finally, cognitive flexibility may be related to the ability to apply emotion regulation strategies flexibly across contexts. Cognitive flexibility is the ability to selectively switch among mental processes to generate appropriate emotional and behavioral responses to a changing environment (Dajani & Uddin, 2015; Scott, 1962). In other words, cognitive flexibility includes set shifting, task switching, and mental creativity. Set shifting is the ability to transition between
cognitive-attentional sets, or groups of rules that define the property of stimuli that are relevant in given trials (e.g., attend to colors of cards then to shapes). Task switching is the ability to flexibly change actions in response to different goal states (e.g., classify numbers as odd or even then as greater or less than 10). Mental creativity is essentially “thinking outside the box,” or the ability to identify alternative solutions to problems. Cognitive flexibility appears to build on working memory to maintain multiple rule representations and on inhibitory control to override prepotent responses in different situations (Dajani & Uddin, 2015; Diamond, 2013). For instance, cognitive flexibility includes being able to change perspectives spatially and interpersonally. To change perspectives, an individual needs to inhibit their previous perspective and load a different perspective onto working memory (Diamond, 2013). Additionally, cognitive flexibility includes being able to change how one thinks about a problem and generate new approaches to solving it.

To date, few studies tie cognitive flexibility directly to emotion regulation. Gyurak et al. (2009) exposed participants to a startle stimulus and measured downregulation, operationalized as reduction in body movement and emotional facial behavior, when warned about the stimulus compared to when unwarned. They found that greater cognitive flexibility was associated with more effective emotion regulation, both when participants were given explicit instructions to downregulate and when given no instructions. Similarly, other studies found that greater ability to shift among mental sets was associated with more successful reappraisal and/or expressive suppression (Hendricks & Buchanan, 2016; Liang et al., 2017). However, some studies found no relationship between cognitive flexibility and rumination (Aker et al., 2014) or reappraisal (Hendricks & Buchanan, 2016; Sperduti et al., 2017).

**Measuring Executive Functioning**
To measure executive functioning, researchers sometimes use self-report measures but often rely on behavioral tasks in addition or instead. Questionnaires generally assess how successful individuals are at specific behaviors that require executive functions to perform by asking how much they agree with experiential statements. For instance, “It’s easy for me to adapt to new changes in my environment,” is a question from the Eating Disorder Flexibility Index Questionnaire that assesses cognitive flexibility (Dahlgren et al., 2019). Hence, questionnaires provide a subjective assessment of executive functioning from the viewpoint of the respondent. Behavioral tasks are more objective assessments that require participants to complete activities that rely on specific executive functions, processes which individuals may have limited insight into, to perform successfully.

**Measuring Inhibitory Control.** Inhibitory control tasks measure participants’ ability to delay or withhold a prepotent response and/or to instead perform a subdominant response. The prepotent response may be conditioned in participants through practice on early trials of a task. Tasks that measure inhibitory control include Stroop tasks, Simon tasks, Flanker tasks, antisaccade tasks, go/no-go tasks, and stop-signal tasks. In Stroop tasks, participants respond to neutral (e.g., color words displayed in black ink), congruent (e.g., color words displayed in matching ink, such as “pink” written in pink), and incongruent stimuli (e.g., color words displayed in non-matching ink, such as “pink” written in green ink; Stroop, 1935). In Simon tasks, participants respond differentially to stimuli (e.g., making a rightward response to a circle and a leftward response to a square) that are presented in a congruent (e.g., circle on the right of a display) or incongruent manner based on a feature of the response (e.g., circle on the left of the display; Simon & Wolf, 1963). In Flanker tasks, participants directionally respond (e.g., pressing left or right arrow) to a target stimulus that is flanked by stimuli that are neutral, congruent (e.g.,
correspond to the same directional response as the target), or incongruent (e.g., correspond to the opposite directional response as the target; Eriksen & Eriksen, 1974). In antisaccade tasks, participants fixate on a motionless target and then attempt to direct their eye movements in the opposite direction of a presented stimulus (e.g., to inhibit the reflexive response to saccade towards the presented stimulus; Hallett, 1978). In go/no-go tasks, participants respond to certain presented “go” stimuli (e.g., press the space bar in response to the letter “x”) and withhold responding to other “stop” stimuli (e.g., exhibit no response for other letters). Recently, researchers have demonstrated go/no-go tasks may be a better measure of response selection than more complex inhibitory control (Raud et al., 2020); stop-signal tasks are variations of go/no-go tasks that may be more appropriate for assessing inhibitory control. In stop-signal tasks, participants are asked to respond differentially to stimuli as quickly as possible (e.g., press “z” for vowels and “m” for consonants) but to withhold responses on trials with countercommands (e.g., a trial where a vowel is presented and then is surrounded by a red circle indicating no response should be made; Lappin & Eriksen, 1966; Verbruggen & Logan, 2008).

Behavioral indices used to quantify inhibitory control include percentage of correct trials, commission errors (false alarms), and omission errors (misses), which all assess behavioral accuracy. Additionally, stop-signal reaction time, or the duration of time it takes to “stop” a prepotent response when presented with a signal to do so, is an important measure of inhibitory control. Stop-signal reaction time is not directly observable because no response is initiated on successfully inhibited trials. Instead, stop-signal reaction time is calculated using the probability of responding given a stop signal (e.g., probability of commission errors) and the distribution of no-signal reaction times (e.g., go trial reaction times; Logan & Cowan, 1984).
**Measuring Working Memory.** Working memory behavioral tasks measure participants’ ability to mentally hold, update, and recall information. Tasks used to measure working memory include simple and complex span tasks and n-back tasks. Span tasks require participants to repeat lists or sequences of visually- or auditorily-presented items in the correct order; tasks that use numbers are known as digit span tasks. There is significant ongoing debate in the cognitive psychology field whether simple span tasks really measure working memory because they do not require manipulation of the stored material (Conway et al., 2002; Unsworth et al., 2007). Complex span tasks, by contrast, combine a memory span measure with a concurrent processing task. Complex span tasks include reading span, in which participants read sentences and try to remember the last word of each sentence (Daneman & Carpenter, 1980), and operation span, in which participants remember sequentially presented words while simultaneously solving math problems (Turner & Engle, 1989). In n-back tasks, participants report whether a presented stimulus item matches the item presented “n” trials prior (Jaeggi et al., 2010; Kirchner, 1958), requiring them to constantly maintain and update relevant stored information.

Span tasks generally provide a measure of working memory capacity as the highest number of presented items successfully repeated. Behavioral indices from n-back tasks include reaction time (i.e., response latencies, or how long it takes participants to respond correctly to matching trials) and accuracy, measured by percentage of trials answered correctly, number of commission errors, and/or number of omission errors (Meule et al., 2017).

**Measuring Cognitive Flexibility.** Cognitive flexibility behavioral tasks measure the ability to shift between different task rules and corresponding responses. Tasks used to measure cognitive flexibility in adults include selection and categorization tasks, such as the Intra-Extra Dimensional Set Shift task and Wisconsin Card Sorting Test. In the Intra-Extra Dimensional Set
Shift task, participants learn a rule (e.g., select the longer white line) to determine which stimuli are correct by receiving feedback on their selections and then, after a certain number of correct responses, the rule changes. The stimuli complexity increases as the task progresses and the rule shifts change from intra-dimensional (e.g., white lines are the only relevant dimension) to extra-dimensional (e.g., pink shapes underlying the white lines become the relevant dimension; Barnett et al., 2010; Roberts et al., 1998). In the Wisconsin Card Sorting Test, participants are asked to match cards based on shared qualities of color, number, or shape of stimuli on the cards; participants are not told the matching rule but do receive feedback, and over time the matching rule changes (Berg, 1948; Grant & Berg, 1948; Nyhus & Barcelo, 2009).

Behavioral indices used to quantify cognitive flexibility from categorization tasks include number of trials completed, number of stages or rule sets completed, response latency (i.e., reaction time), and number or percentage of total, perseverative, and non-perseverative errors made. Perseverative errors are errors that occur due to continued use of an outdated rule to select or sort material.

**Measurement Limitations.** Given heterogenous study findings, it is important to note the limitations of measuring specific executive functions and emotion regulation. As mentioned, inhibitory control, working memory, and cognitive flexibility are interrelated cognitive processes. Therefore, selecting tasks that are pure measurements of one process or that delineate clear boundaries among these executive functions is difficult, if not impossible. This difficulty is enhanced due to terminological inconsistency in the literature. For instance, recent versions of Stroop tasks include an inhibition/switching condition (e.g., for some items, participants should read the word aloud, whereas for other items they should name the color of the ink), which
appears to assess both inhibitory control and cognitive flexibility indistinguishably from each other.

Relatedly, many research designs use executive function tasks that include emotional stimuli, making it challenging to isolate the contribution of cognitive processes to emotion regulation (e.g., Hendricks & Buchanan, 201; McRae et al., 2012). Most relevant studies also assess short-term strategy implementation, without addressing the application of emotion regulation strategies flexibly across contexts (e.g., Hendricks & Buchanan, 201; McRae et al., 2012). Pruessner et al. (2020) suggest that many laboratory tasks may not place sufficiently high demand on executive functions and that these cognitive processes are particularly important to emotion regulation in novel or dynamic situations.

**Neural Substrates of Executive Functioning**

Similar to emotion regulation, executive functioning is a set of complex processes realized by intricate and distributed neural systems. Included here is a relatively brief summary of major findings from experimental neuroscience and review studies; for more detailed information, see comprehensive reviews and meta-analyses (Bari & Robbins, 2013; D’Esposito et al., 2000; Funahashi, 2017). Evidence from functional neuroimaging converges on the prefrontal cortex as the primary brain region involved in executive functioning, with multiple neuronal connections to other cortical, subcortical, and brainstem regions.

The frontal cortex has been implicated in inhibitory control since the late 1800s (Ferrier, 1876, as cited in Bari & Robbins, 2013). Specifically, animal lesion studies have suggested inhibitory functioning is localized to the dorsolateral prefrontal cortex, inferior orbitofrontal cortex, and/or inferior frontal cortex (see Roberts & Wallis, 2000 for a review). Behavioral studies of human patients with unilateral prefrontal lesions support localization to the right
inferior frontal cortex (Aron et al., 2004). Functional neuroimaging studies show activation in the middle and inferior frontal gyri, frontal limbic area, anterior insula, and inferior parietal lobe during successful inhibition of prepotent motor responses (Garavan et al., 1999). This is suggestive of a primarily frontal, right-hemisphere dominated cortical network of inhibitory control. Additional findings support such a network, with emphasis placed on the role of the anterior cingulate cortex and orbitofrontal cortex (Carter et al., 2000; Casey et al., 1997).

The frontal cortex has also been suggested to underlie working memory (Baddeley, 1992). Animal lesion studies of the bilateral prefrontal cortex have demonstrated deficits in working memory delayed-response tasks even before working memory was explicitly defined as a construct (Jacobsen, 1936, as cited in Funahashi, 2017). More recent animal lesion studies have shown specifically that the dorsolateral prefrontal cortex, particularly the area surrounding the principal sulcus, appears involved in maintenance and updating of information (Curtis & D’Esposito, 2004). Functional neuroimaging studies in humans generally support this, finding that the lateral prefrontal cortex is involved in encoding, response-related processes, and mnemonic and non-mnemonic processes engaged during the temporary maintenance of information (D’Esposito et al., 2000).

Though the frontal cortex is implicated in executive functions generally, the neural architecture of cognitive flexibility appears somewhat more distributed than that of inhibitory control or working memory. Several reviews have found highly variable patterns of brain activity during cognitive flexibility tasks (Arden et al., 2010; Dietrich & Kanso, 2010). This makes sense given the aforementioned complexity of flexibility as a cognitive process. Still, studies have also found significant activation of the prefrontal cortex. For instance, in a cognitive set-switching paradigm, Kim et al. (2011) found domain-preferential prefrontal cortex activations across lateral
and medial prefrontal cortex with progressively more rostral regions activated as switches increased in abstractness. Additionally, lesions in the prefrontal cortex of rats have demonstrated causal impairment in a reward-discounting choice task thought to require cognitive flexibility (Gruber et al., 2010). Finally, a meta-analysis found bilateral activation in the prefrontal cortex, the anterior cingulate cortex, and inferior parietal lobule across studies using the Wisconsin Card Sorting Task (Buchsbaum et al., 2005).

Whereas identifying specific neural mechanisms underlying cognitive processes is difficult, the evidence overwhelmingly points to the role of a primarily frontal distributed cortical network of executive functioning. Specific areas indicated in this network include the dorsolateral prefrontal cortex, orbitofrontal cortex, and anterior cingulate cortex. This network appears to overlap significantly with that involved in emotion regulation. Specifically, the dorsolateral prefrontal cortex and orbitofrontal cortex have been implicated in emotion and memory (Rosenbloom et al., 2012). Meanwhile, the anterior cingulate cortex is uniquely positioned in the brain with connections to the emotional limbic system and cognitive prefrontal cortex, likely maintaining an important role in integration of neuronal circuitry for emotion regulation (Stevens et al., 2011).

**Improving Emotion Regulation and Executive Functioning Via Exercise**

Emotion regulation is a critical component of well-being, and deficits in emotion regulation play a transdiagnostic role in maladaptive behavior and psychopathology. Hence, psychology and other fields are invested in finding strategies to improve emotion regulation abilities. For instance, therapeutic approaches often emphasize or incorporate interventions designed to directly target emotion regulation abilities. A notable example is dialectical behavior therapy, which explicitly incorporates emotion regulation skills training as one of its four core
modules (Linehan, 1993; Neacsiu et al., 2014). Dialectical behavior therapy teaches strategies based on Gross’s (1998, 2015) cognitive control process model of emotion regulation, as well as strategies to manage emotional vulnerability, enact change (biological, experiential, cognitive, action, and expression), and process/change emotional aftereffects. Some examples of these skills include controlling the focus of attention via mindfulness, radical acceptance to encourage reappraisal, and engaging in opposite action to change both actions and associated emotions (Linehan, 1993; Neacsiu et al., 2014). The use of such emotion regulation skills training has demonstrated improvements in participants’ self-reported reactivity to an emotional stressor at the end of a seven-week treatment paradigm and in overall emotion regulation at follow-up seven weeks post-treatment (Dixon-Gordon et al., 2015).

Another therapeutic approach that targets emotion regulation is the aptly-named emotion regulation therapy (Mennin et al., 2013). Emotion regulation therapy is a mechanism-focused treatment that draws from an affective science framework to target motivational mechanisms, regulatory mechanisms, and contextual learning consequences. It instructs individuals to engage in mindful skills to counteract maladaptive regulation tendencies, including worry, rumination, and self-criticism. Preliminary studies of this approach demonstrate decreases in these maladaptive tendencies, severity of psychopathology (specifically depression and anxiety), and improvement in quality of life (Mennin et al., 2015; Renna et al., 2018). Furthermore, the addition of emotion regulation training to traditional cognitive behavior therapy (or even the replacement of components of cognitive behavior therapy with emotion regulation training) has been shown to enhance the effects of cognitive behavior therapy on increased skills application (e.g., the ability to modify, accept, and tolerate negative emotions), decreased depression, decreased negative affect, and increased positive affect (Berking et al., 2008).
Other interventions targeting emotion regulation include biofeedback and virtual reality programs. Biofeedback is the process of measuring an individual’s physiological activity and subsequently feeding this information back to the individual. Biofeedback can be provided in laboratory/clinic settings, as home training (ambulatory feedback), or via real-time support in everyday stressful situations (biocueing). A recent review of these biofeedback techniques in both clinical and nonclinical populations found that most of the 21 included studies demonstrated significant positive effects on self-reported psychological measures, most notably those related to stress (Harmsel et al., 2020). Similarly, a meta-analysis of 11 studies in adults and older adults suggested that virtual reality-based emotion regulation training can promote well-being in both clinical and healthy populations (Montana et al., 2020).

Another intervention modality for improving emotion regulation may be through exercise and/or sports participation. Indeed, research has found that some individuals intentionally use exercise, among other behaviors, to regulate their moods (Thayer et al., 1994). Numerous studies show overall positive associations between exercise, particularly aerobic exercise, and mood or emotional well-being (Goodwin, 2003; Hansen et al., 2001; Liao et al., 2015; see Reed & Ones, 2006; see Salmon, 2001). One long-held hypothesis is that aerobic exercise relieves depressive and/or anxious symptoms through recurrent improvements in short-term affect, which hypothetically leads to long-term mood elevations. Whereas some studies have found null results (Krogh et al., 2012; Rejeski et al., 1995), other studies and meta-analyses document short- or long-term mood improvements after exercise (Blumenthal et al., 2007; Reed & Ones, 2006; Shuch et al., 2016; Wipfli et al., 2008). These equivocal findings may be explained, somewhat, by inconsistencies in type of intervention (e.g., aerobic versus anaerobic exercise), length of intervention, and populations studied (e.g., habitual exercisers versus sedentary individuals,
clinal versus nonclinical populations, different age groups). In general, exercise increases positive and decreases negative emotions (Yeung, 1996), and long-term exercisers usually experience improved mood from consistent engagement. Moreover, in studies of individuals with depression and/or anxiety, aerobic exercise programs have demonstrated treatment effects comparable to antidepressants and psychotherapy (Kvam et al., 2016; Stonerock et al., 2015).

The literature on exercise’s influence on emotion regulation abilities, particularly as the mechanism through which exercise may improve general mood or overall well-being, is more limited. In an early study, individuals who participated in a twelve-week fitness-enhancing exercise program returned to their physiological baseline more quickly than non-program participants after exposure to a stressor (Calvo et al., 1996). In another study, individuals in a two-month exercise program demonstrated significant improvements in cognitive and behavioral self-regulatory capacity, as well as reported significant decreases in perceived stress and emotional distress, compared to a control group (Oaten & Cheng, 2006).

More recently, a pilot study (Bernstein & McNally, 2016) investigated whether aerobic exercise helped individuals with emotion regulation deficits recover more quickly from positive and negative mood inductions. Participants were randomized to 30 minutes of either jogging or stretching. Participants in both groups who reported greater emotion regulation difficulties experienced more persistent stressor-induced sadness, compared to those participants who reported fewer emotion regulation difficulties. However, exercise (i.e., jogging) participants were less affected by these difficulties and reported less sadness at the end of the study, suggesting improved down-regulation of negative emotions. Specifically, the authors noted that exercise participants were better able to overcome regulation difficulties that appear to rely heavily on executive control or functioning, such as difficulties in strategy generation and goal-
directed behaviors (Bernstein and McNally, 2016). The same research group conducted a methodologically similar study with a heterogenous sample of sedentary and active individuals. Self-reported regular exercise was associated with less depression and less anxiety; these relationships were fully mediated by habitual rumination (which was negatively correlated with regular exercise) and by coping self-efficacy (which was positively correlated with regular exercise). Immediately following a stressor task, there were no differences between exercise (i.e., cycling) and stretching groups in negative affect or in reported difficulties with emotion regulation. However, a three-way interaction was found among time post-stressor, group, and state rumination. Specifically, participants in both conditions with low state rumination reported declines in negative affect by the end of the study, approximately 15 minutes after exposure to the stressor. For participants with high state rumination, only those in the exercise group reported similar declines. A similar three-way interaction emerged among time post-stressor, group, and difficulty accessing regulatory strategies. This suggests acute exercise attenuated the effects that rumination and emotion regulation difficulties have on delaying emotional recovery (Bernstein & McNally, 2018). Finally, the same researchers also conducted a within-subjects study in which participants completed three laboratory visits including an experimental stressor and cycling, stretching, or resting. Similar to the aforementioned study, greater self-reported rumination in response to the stressor predicted more persistent negative affect. This affect was attenuated by cycling (but not by stretching or resting) both 5 and 15 minutes post-stressor, providing further evidence that acute exercise may hasten emotional recovery, at least for individuals who tend to ruminate (Bernstein & McNally, 2017).

Exercise may also improve executive functions which are related to, or even underlie, emotion regulation. A recent meta-analysis of studies of children through young adults yielded
significant moderate effect sizes of acute aerobic exercise’s positive effect on executive functions in general and inhibitory control in particular, though not on working memory (Verburgh et al., 2013). Studies of acute exercise’s effects on working memory have been mixed (Martins et al., 2013; McMorris et al., 2011; Verburgh et al., 2013). Chronic exercise appears to be associated with better inhibitory control and working memory (Padilla et al., 2014; Padilla et al., 2013). The aforementioned meta-analysis did not reveal an overall effect of chronic physical exercise on executive functions but only included five studies in that specific analysis (Verburgh et al., 2013). A recent community-based trial randomized adults ages 20 to 67 to participate in regular (i.e., four times weekly) aerobic exercise or stretching/toning over six months. Executive functioning, as measured by a combination of a cognitive flexibility and a working memory task, improved significantly in the exercise condition, with the effect moderated by age such that improvement was more pronounced as age increased (Stern et al., 2019). Interestingly, this study also included separate measures of working memory, a construct the authors distinguished from executive functioning, which did not show improvement as a result of aerobic exercise. Given the associations between emotion regulation and executive functioning mentioned earlier, exercise may promote improved emotion regulation through mechanisms of improved executive functioning.

Unfortunately, studies of the impact of exercise on executive functions in healthy populations are limited in number and scope. Specifically, most studies involve only older adults as this population is generally most likely to experience age-related cognitive declines. Many studies also use the construct of physical fitness as a proxy for exercise, which presents concerns about the interpretation of results as they relate to exercise since aerobic fitness depends partially on genetic factors (Levine, 2008).
Athletes constitute a self-selected sample pool for studying potential effects of habitual exercise on emotion and cognition, though causality of any associations are difficult to determine. Theoretically, habitual exercise could improve emotion regulation and executive functioning, but individuals with greater emotion regulation or executive functioning abilities may also be more likely to engage in regular exercise or to pursue sports participation at a higher level. There could also be a positive feedback loop effect, whereby individuals with greater emotion regulation or executive functioning engage in more habitual exercise, which further improves emotion regulation and executive functioning.

To date, most studies on athletes are conducted from a sports psychology perspective, focusing on improved performance rather than psychological functioning. Few studies examine emotion regulation, executive functioning, or psychopathology specifically in college athletes compared to non-athletes or among athletes engaged in different sports. One study found that female college athletes, compared to non-athletes, reported significantly fewer emotion regulation difficulties, as well as fewer symptoms of disordered eating. Additionally, emotion regulation difficulties partially mediated the effect of athletic status on disordered eating (Wollenberg et al., 2015). Another study found no differences in psychiatric symptom severity between recreational collegiate athletes and National Collegiate Athletic Association athletes, but both athlete groups reported significantly less severe global psychiatric symptoms when compared with a non-athlete sample (Donohue et al., 2004). Regarding executive functioning, studies have shown athletes perform better than non-athletes and suggest there may also be differences in performance among different types of sports (Jacobson & Matthaeus, 2014; Vestberg et al., 2012).
Mindful Exercise, Emotion Regulation, and Executive Functioning

Given the premise that exercise may improve emotion regulation and executive functioning, a logical follow-up inquiry is whether certain types of exercise – specifically those that explicitly work to strengthen relevant skills and capabilities – are more beneficial than others. Recently, investigators have started to examine benefits of mind-body, or mindful, exercise. Mindful exercise has been characterized as physical exercise executed with a profound inwardly directed contemplative focus (IDEA Mind-body Fitness Committee 1997-2001, as cited by La Forge, 2016). In other words, mindful exercise is exercise that incorporates mindfulness, or non-judgmental attention directed towards perceptual experience, such as interoceptive and proprioceptive sensations. Researchers have cited yoga, qi gong, and tai chi as the earliest, quintessential forms of mindful exercise (La Forge, 2016). Yoga is a group of physical, mental, and spiritual disciplines that include breathing exercises, postures, chants, and/or meditation. Qi gong is a system of coordinated body posture, slow flowing movement, deep rhythmic breathing, and meditation. Tai chi is a martial art focused on meditation and self-defensive movement.

Initial research points to emotion regulation and executive functioning benefits of yoga. In a randomized controlled trial of high school students, participants assigned to a 16-week yoga intervention reported significantly more improvement in emotion regulation from beginning to end of the program than those assigned to comparable physical education (Daly et al., 2015). Kobylinska et al. (2018) examined the use of cognitive reappraisal and expressive suppression in yoga practitioners and found that participants who had practiced yoga for a longer period of time (i.e., at least one year) reported using cognitive reappraisal more often than those who had practiced for a shorter period of time. Additionally, engagement in yoga, compared to exercise or stretching, has been shown to be related to improved performance on tasks of inhibitory control.
in prison populations (Bilderbeck et al., 2013), working memory and task switching in older adults (Gothe et al., 2016), and inhibitory control and working memory in young adult women (Gothe et al., 2013). Few studies have directly examined the benefits of qi gong or tai chi on emotion regulation or executive functioning, but a review of randomized controlled trials and meta-analyses found that both exercises reduced symptoms of anxiety and depression (Yeung et al., 2018). Liu et al. (2018) found that older adults with long-term tai chi experience reported greater emotion regulation than age-matched controls. Zhang et al., (2016) found that a qi gong training program improved emotion regulation in patients with chronic obstructive pulmonary disease.

La Forge (2016) suggests that mindful exercise requires more than merely adding a cognitive component to conventional physical activity. He recommends that mindful exercise includes meditation/contemplation (i.e., non-judgmental, present-moment introspection), proprioceptive and kinesthetic body awareness (i.e., low-level muscular activity coupled with mental focus on muscle and movement sense), breathwork (i.e., breath centering techniques), anatomic alignment or proper choreographic form (i.e., practice of particular movement patterns or postures), and intrinsic energy (i.e., movement and flow of chi or other positive energy). Other activities have been suggested as contemporary mindful exercises, including martial arts.

**Potential Benefits of Taekwondo**

Colloquial wisdom has long touted the benefits of martial arts; over the last 50 years, empirical research has begun to investigate these claims more critically (see Binder, 1999 and Martin, 2006 for early reviews). Martial arts focus on both physical and cognitive fitness, incorporating elements of mindfulness and emphasizing self-control, discipline, and character development. Taekwondo is an exemplar martial art, classified as a physical activity of vigorous
intensity based on its energy expenditure (Ainsworth et al., 2000). Recognized as an official Olympic sport in 2000 and contested as a demonstration event since 1988, taekwondo is globally popular with an estimated 80 million practitioners in 210 countries (World Taekwondo, 2020). Based on the definition above, taekwondo is also mindful exercise.

Taekwondo is characterized by aerobic exercise in the form of kicking drills, striking drills, basic exercises (e.g., high knees, sprinting, lunges, squats, pushups), sparring (i.e., rule-based fighting), and poomsae (i.e., sets of choreographed movements that simulate fighting imaginary opponents). Most curriculums also include less aerobic activities, such as meditation, self-defense practice, and strength training. Notably, the primary competition events for taekwondo, sparring and poomsae, require significant mind-body engagement. To excel at these events, practitioners must be highly aware of and in control of both their breathing and movement. Sparring entails the ability to inhibit prepotent autonomic responses at times (inhibitory control), maintain fighting rules and effective counterattacks in mind (working memory), and flexibly switch among offensive and defensive strategies based on the movements and style of an opponent (cognitive flexibility). Similarly, poomsae requires both the initiation and stoppage of specific, sometimes physically uncomfortable or awkward body movements (inhibition), maintenance of precise standards and specific sequences of movement (working memory), and adjustments based on environmental and judging context (cognitive flexibility). As Diamond (2011) posits, cognitively-engaging exercises, especially those which require hand-eye coordination, crossing the body’s midline, and/or rhythmic movement, might be especially beneficial for executive functioning.

Given taekwondo’s global popularity, relatively few studies have been conducted examining potential emotion regulation-related benefits of taekwondo, particularly with Western
or college-aged populations. Toskovic (2001) found that a single 75-minute session of taekwondo practice increased positive mood and decreased negative mood in novice college taekwondo participants, compared to control participants. However, this study was likely under-powered as it included only 20 participants in each group (Toskovic, 2001). In a study of 47 taekwondo practitioners, increased training frequency was negatively associated with anger expression and positively associated with emotional control, suggesting a possible “dose-response” curve of taekwondo practice on emotion regulation (Ortenburger et al., 2015).

A growing body of literature has examined potential executive function benefits of taekwondo, though most of these studies have looked at child participants. In two separate studies, Cho and colleagues found improvement in inhibitory control tasks in Korean children assigned to 16 weeks of taekwondo training compared to controls (Cho, Kim, & Roh, 2017; Cho, So, & Roh, 2017). Similarly, in a sample of Korean undergraduate students, participants \( (n = 7) \) who underwent an 8-week taekwondo exercise program performed better than controls \( (n = 7) \) on a test of inhibitory control (Kim, 2015). In “The Healthy For Life Taekwondo Pilot Study,” researchers incorporated taekwondo into middle school physical education two times a week for nine months. Compared to a control group, the taekwondo group performed better on the Hearts and Flowers Task (an executive function task considered to produce indices of both inhibitory control and cognitive flexibility that depend on working memory; Diamond et al., 2007; Diamond, 2013), as well as a parent-rated measure of inhibitory control. The majority of the taekwondo group participants also reported perceived improvement in self-control (Lakes et al., 2013). Finally, researchers found moderate improvements in working memory and inhibitory control in taekwondo novices over age 40 who volunteered to participate in one year of age-adapted taekwondo training (Pons van Dijk et al., 2013). Participants also improved on a
measure of cognitive flexibility, though the difference was not statistically significant (Pons van Dijk et al., 2013).

**Sports Participation in the Context of a Global Pandemic**

The present study was conducted approximately one year after the start of the coronavirus (COVID-19) global pandemic and related imposed lockdowns. As with many aspects of functioning, the pandemic and associated safety precautions (e.g., physical distancing, limited-sized gatherings) greatly impacted collegiate sports. The vast majority of collegiate events were cancelled, postponed, or significantly downsized. For instance, nearly all taekwondo competitions in the United States between March 2020 and May 2021 were cancelled, such as the 2020 National Collegiate Taekwondo Association Championships, or conducted remotely, such as the 2021 National Collegiate Taekwondo Association Championships. Additionally, practice and training opportunities were significantly reduced. Researchers are only starting to assess this impact on collegiate athletes in meaningful ways. One early study of Spanish university athletes found significant decreases in autonomous goal motives and eudaimonic well-being, or subjective vitality, from prior to the start of the pandemic (Martinez-Gonzalez et al., 2021). Studies of non-college semi-elite and elite athletes have found self-reported decreases in training intensity and training volume (Mon-Lopez et al., 2020), reduced sleep quality (Mon-Lopez et al., 2020; Pillay et al., 2020), worsened nutritional intake (Roberts et al., 2020; Pillay et al., 2020), and perceived reduction in psychological health (Hakansson et al., 2020; Pillay et al., 2020). To our knowledge, no studies have investigated impacts of COVID-19 on training volume and intensity and perceptions of team closeness and supportiveness in collegiate athletes, so we include that here as a secondary aim.
The Current Study

The current study examined the potential impact of regular taekwondo practice on emotion regulation and executive functioning by examining differences in these variables among college student groups of regular taekwondo practitioners, non-taekwondo athletes, and non-athletes. Research suggests exercise may improve emotion regulation, perhaps via improvement in associated cognitive processes. Colloquial wisdom and initial research suggest that sports which incorporate mind-body foundations, or mindful exercise, may be especially worthwhile interventions for such improvement. Taekwondo is a prime example of such a sport, especially given its global popularity. However, limited research, mostly undertaken with child populations and/or populations outside of the United States, has investigated potential affective and cognitive benefits of taekwondo. To our knowledge, no other study has examined emotion regulation and executive functioning in collegiate taekwondo athletes. Therefore, the current project had the following specific aims and associated hypotheses:

1. **Aim 1:** Examine differences in emotion regulation and related dysregulation, depression, anxiety, and stress among a previously unstudied population of taekwondo student athletes, non-taekwondo (i.e., other) student athletes, and non-athlete students.

   *Hypothesis 1:* Taekwondo athletes, compared to other athletes and non-athletes, will endorse more frequent use of adaptive emotion regulation strategies and less frequent use of maladaptive emotion regulation strategies; fewer difficulties in emotion regulation; and less recent experience of depression, anxiety, and stress.

2. **Aim 2:** Examine differences in executive function among a novel population of taekwondo athletes, other athletes, and non-athlete college students.
Hypothesis 2: Taekwondo athletes, compared to other athletes and non-athletes, will perform better on tasks measuring inhibitory control, working memory, and cognitive flexibility.

3. Aim 3: In a population of taekwondo student athletes, evaluate whether a “dose-response” curve exists between years of practice, frequency of practice, and/or experience level and emotion regulation and executive functioning.

Hypothesis 3: More experienced and engaged taekwondo athletes (i.e., those who have trained longer, who train more frequently, and/or who have achieved higher belt ranks), compared to less experienced taekwondo athletes, will endorse more frequent use of adaptive emotion regulation strategies, less frequent use of maladaptive emotion regulation strategies, fewer difficulties in emotion regulation, and less recent experience of depression, stress, and anxiety and will perform better on tasks of executive functioning.

4. Secondary aim 4: Explore the impact of the COVID-19 pandemic on taekwondo and other athlete’s participation and perceived benefits of being part of a club or team sport.

Hypothesis 4: Athletes, both taekwondo and non-taekwondo, will endorse participating less frequently in their primary sport, perceiving themselves as less close to their team members, and perceiving themselves as less supported by their teams at the time of study completion compared to prior to the onset of the COVID-19 pandemic and physical distancing restrictions.
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 purpose and nature of the research and confirmed consent prior to beginning the study.

Participants

Participants (N = 318) were student athletes (n = 96) and non-athletes (n = 159) at a large university in the Northeast and student taekwondo athletes (n = 63) from colleges and universities located primarily in the Northeast. We recruited non-taekwondo participants using the primary university’s psychology research pool, through which undergraduate students participate in studies for credit in psychology courses. We recruited taekwondo participants via emails sent to two regional collegiate taekwondo listservs, which were then forwarded by team leaders and coaches directly to student athletes. We collected data between March and May 2021. To participate, students needed to be at least 18 years of age and currently enrolled at the primary university (research pool participants) or at another college/university and part of its taekwondo club. There were no other explicit inclusion or exclusion criteria.

Procedures

Participants completed questionnaires via the secure survey platform Qualtrics. Behavioral tasks were administered via the secure web-based research platform PsyToolkit (Stoet, 2010; Stoet, 2017), through a link embedded in the Qualtrics survey. These tasks (i.e., stop-signal, n-back, Wisconsin Card Sorting Task) were freely available versions accessed through the PsyToolkit Experiment Library. Participants completed study components in the following order: demographic and activity survey, Cognitive Emotion Regulation Questionnaire, Difficulties in Emotion Regulation Scale, n-back task, stop-signal task, Wisconsin Card Sorting
Task, Depression Anxiety and Stress Scales, and Eating Disorder Flexibility Index

The behavioral tasks were administered in between questionnaires to reduce survey fatigue; they were presented as a block (rather than alternating between surveys and individual tasks) to reduce burden on participants who needed to enter a unique code in Qualtrics after completing the tasks to allow for the matching of questionnaire self-report and behavioral task data. Requiring participants to enter this unique code also served as a check of participant attention and engagement. Upon completion of the study, participants provided their email addresses using a separate embedded survey link so that they were not associated with individual survey responses. Using these provided email addresses, researchers awarded one study credit to research pool participants and a $10 Amazon gift card to taekwondo participants. Two participants declined to accept the gift card.

Measures

Demographic and Activity Survey

A brief demographic and activity survey collected participants’ self-reported age, race, ethnicity, sex assigned at birth, gender identity, class year, and general living situation information (e.g., on-campus, off-campus near their college/university, off-campus in the same state, out of state). Research pool participants self-reported whether they were athletes or not, after being provided with the definition of an athlete as “an individual who trains and/or competes in an identified sport individually or as part of a club/team.” Non-athletes provided information about their general level of engagement in physical activity. Athletes answered questions about their primary sport (i.e., name of sport; individual or group format; varsity, intramural, or private club/team), any additional sports they engage in, how long they have trained in their primary sport, their current modality of training (i.e., virtually, in-person, hybrid),
and how many other individuals they currently train with. They also provided information on the
following topics both retrospectively before the COVID-19 pandemic (i.e., before March 2020)
and at the time of survey completion: average days a week spent training, average hours a week
spent training, average number of competitions attended in a year or competition season, how
close they felt to their club/team members, how supported they felt by their club/team.
Taekwondo athletes also provided information about their experience level (i.e., current belt
rank), degree to which they previously competed in events (i.e., poomsae, sparring), future
events they anticipate competing in, and the percentage of training time allotted by their club to
various activities (i.e., general techniques, poomsae techniques, practicing poomsae, sparring
techniques, practicing sparring, self-defense, meditation/mindfulness, other) before March 2020
and at the time of survey completion. These variables were assessed as potential covariates in the
planned analyses and to gain a richer understanding of how training experiences may have
changed between the start of the pandemic and the time of data collection.

**Cognitive Emotion Regulation Questionnaire**

The Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski et al., 2001) is a 36-
item self-report questionnaire that measures habitual use of nine cognitive emotion regulation
strategies following stressful life events: 1) self-blame, or thinking that oneself is at fault for
what they have experienced, 2) acceptance, or thinking that resigns oneself to what has
happened, 3) rumination, or repetitive thinking about feelings and thoughts associated with
stressful events, 4) positive refocusing, or thinking of other, pleasant matters, 5) refocus on
planning, or thinking about steps to take to deal with what has happened, 6) positive reappraisal,
or attaching a positive meaning to stressful events in terms of personal growth, 7) putting into
perspective, or thinking the events are less serious compared to other stressful events, 8)
catastrophizing, or explicitly emphasizing the negatives of the events, and 9) other-blame, or thinking that places the blame for what one has experienced on others. Participants rate how personally applicable statements are on a five-point Likert-type scale ranging from Almost Never (1) to Almost Always (5). Higher subscale scores indicate greater (i.e., more frequent) use of those strategies.

Past research has supported the CERQ’s psychometric properties in adults (subscale α’s = .75 to .87; Garnefski & Kraaij, 2007). In the present study, subscale reliability coefficients for all respondents combined ranged from acceptable to good (four items each; self-blame: α = .76, acceptance α = .71, rumination α = .71, positive refocusing α = .82, refocus on planning α = .80, positive reappraisal α = .85, putting into perspective α = .81, catastrophizing α = .73, and other-blame α = .77). The CERQ was included here to capture the self-regulating, conscious cognitive components of emotion regulation separate from its behavioral aspects. It has recently been used in the realm of sports to investigate whether use of generally adaptive or generally maladaptive strategies differs by athletes’ competitive level, gender, or sport (Costa et al., 2020; Shirvani et al., 2015).

**Difficulties in Emotion Regulation Scale**

The Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004) is a 36-item questionnaire (α = .94 for the total score in the present sample) that measures six dimensions of deficits in emotion regulation: nonacceptance of emotional responses (six items; α = .90), difficulty engaging in goal-directed behavior (five items; α = .86), impulse control difficulties (six items; .88), lack of emotional awareness (six items; .84), limited access to emotion regulation strategies (eight items; α = .90), and lack of emotional clarity (five items; α = .79). Participants rate how personally applicable statements are on a five-point Likert-type scale
ranging from Almost Never (1) to Almost Always (5). Higher scores indicate greater difficulty regulating emotions. Past research has supported the psychometric properties of the questionnaire (subscales and total scale α’s > .80; Gratz & Roemer, 2004).

The DERS was included here to quantify different aspects of deficits in emotion regulation. The DERS is commonly used to examine emotion regulation in collegiate athlete samples (Kucharski et al., 2018; Shriver et al., 2016). Additionally, previous studies have utilized the DERS to compare emotion regulation in athletes and non-athletes (Wollenberg et al., 2015) and to investigate the role of exercise on emotion regulation (Bernstein & McNally, 2018).

**Depression Anxiety Stress Scales**

The Depression Anxiety Stress Scales 21-item version (DASS-21; Lovibond & Lovibond, 1995) is a self-report measure of states of depression, anxiety, and stress. Participants rate how personally applicable statements have been over the past week on a four-point Likert-type scale ranging from Did not apply to me at all (0) to Applied to me very much or most of the time (3). Higher scores indicate greater recent experience of depression, anxiety, and/or stress. The depression subscale (seven items; α = .91 in the present sample) assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest/ involvement, anhedonia, and inertia. The anxiety subscale (seven items; α = .86) assesses autonomic arousal, muscle effects, situational worry, and subjective experience of anxious affect. The stress scale (seven items: α = .84) assesses difficulty relaxing, nervous arousal, being easily upset/ agitated, irritability, over-reactivity, and impatience. The DASS-21 is not diagnostic; rather, it utilizes a dimensional approach to identify the degree of recent depression, anxiety, and stress symptoms experienced by participants. There are also recommended cut-off scores for conventional severity labels of
“normal,” “mild,” “moderate,” “severe,” and “extremely severe” for each subscale (Lovibond & Lovibond, 1995).

The DASS-21 was included here to quantify participants’ recent emotional states of depression, anxiety, and stress. The DASS-21 has previously been used to assess mental health in athletes compared to non-athletes both prior to and since the start of the COVID-19 pandemic (Senisik et al., 2020; Vaughan et al., 2020; Walton et al., 2020).

**Eating Disorder Flexibility Index**

The Eating Disorder Flexibility Index Questionnaire (EDFLIX; Dahlgren et al., 2019) is a 36-item self-report measure of general and eating disorder specific cognitive flexibility. Participants indicate their level of agreement with experiential statements over the past four weeks on a six-point Likert scale ranging from *Strongly Disagree* (1) to *Strongly Agree* (6). The EDFLIX provides a total score (36 items; $\alpha = .87$ in the present sample), as well as subscale scores for general flexibility (17 items; $\alpha = .85$), food and exercise flexibility (13 items; $\alpha = .67$), and weight and shape flexibility (six items; $\alpha = .93$). Higher scores indicate greater cognitive flexibility in those domains. Past research has supported the EDFLIX’s psychometric properties (subscale and total scale $\alpha$’s $> .85$; Dahlgren et al., 2019).

The EDFLIX was included here primarily to provide a self-report measure of general cognitive flexibility to augment data from the behavioral tasks of executive functioning. We administered the full scale to preserve its integrity and psychometric properties and reported the corresponding data. However, an examination of the relationship between eating disorder specific cognitive flexibility (i.e., food/exercise flexibility and weight/shape flexibility) and emotion regulation and other domains of executive functioning is beyond the scope of the
present investigation. Hence, we focus on total and general cognitive flexibility scores in the present analyses.

**Stop-signal Task**

The stop-signal task is an objective measure of inhibitory control that involves concurrent go and stop tasks (Lappin & Eriksen, 1966; Verbruggen & Logan, 2008). The go task is a reaction time task that requires individuals to respond differentially to specific stimuli as rapidly as possible; the stop task involves presentation of another stimulus that countermands the go signal. The stop task occurs randomly and infrequently, on approximately 25% of trials, establishing a prepotent tendency to respond. The stop signal is given after a go-task stimulus is presented, so participants need to regulate a response they may have already initiated. This paradigm provides measures of go-signal and stop-signal reaction times, the latter of which is considered a latency index of internally-generated inhibitory control (Williams et al., 1999). In this study, participants first trained on a go task which required them to respond differentially within 500ms to a green arrow in a white circle pointing either left or right. Participants completed 50 training trials in total or at least 20 training trials accurately. Then, participants had to incorporate the stop task, in which the white circle turned red between 100ms and 450ms after stimulus onset as a cue to inhibit responding. Participants completed 50 task trials, 10 of which (20%) were stop trials. Specific indices generated in this study were go trial reaction time, successful stop rate (percentage of stop trials completed successfully), and commission error rate (percentage of stop trials in which participant responded after presentation of the stop signal); this task administration did not generate a stop-signal reaction time due to a technological limitation. Stop-signal tasks have been used previously to compare inhibition/inhibitory control in athletes and non-athletes (Brevers et al., 2018; Liao et al., 2017; Verburgh et al., 2016).
**N-back Task**

The n-back task is a commonly-used measure of working memory (Jaeggi et al., 2010; Kirchner, 1958). Participants view a sequence of stimuli and must indicate whether each stimulus matches the stimulus presented “n” trials earlier. Successful execution of the task involves maintaining and updating information held in working memory. In this study, we used a 2-back task such that participants were asked to indicate whether each letter presented on screen matched the letter presented two trials previously. Consistent with many versions of this task (Kane & Conway, 2007), each letter was presented for 500ms followed by a 2500ms black period, giving participants a total of three seconds to respond to each trial. The total stimulus set consisted of 15 letters (A, B, C, D, E, H, I, K, L, M, O, P, R, S, T). There were three blocks of 25 trials each; the first block was a training period to orient participants to the task. At the end of each block, participants received detailed feedback on their performance. This study generated the following n-back indices: total accuracy rate (percentage of total trials completed successfully), hit accuracy rate (percentage of match trials completed accurately), and false alarm rate (percentage of commission errors, or trials in which participants erroneously indicated a match). Researchers have previously used n-back tasks to compare working memory in athletes and non-athletes (Schott & Krull, 2019).

**Wisconsin Card Sorting Task**

The Wisconsin Card Sorting Task (WCST) is a frequently-used objective measure of cognitive flexibility (Berg, 1948; Grant & Berg, 1948; Nyhus & Barcelo, 2009). The task requires participants to classify cards according to different criteria, and to use cognitive reasoning or set-shifting abilities to adapt to changing rules. In this study, four cards were presented on screen and participants needed to match consecutive cards from a “pile” to those
four cards by determining which classification rule to use (i.e., color, number, shape, other). Participants received visual and auditory feedback about their choices, and the rule changed every 10 cards. Participants completed 60 total trials. A rate of perseveration based on the number of times participants continued to apply the previous sorting rule was examined as an index of cognitive inflexibility (i.e., fewer perseveration errors indicated greater flexibility). This study generated the following WCST indices: reaction time, total error rate (percentage of total trials that were answered incorrectly), and perseverative error rate (percentage of total trials in which a perseverative error occurred, or in which participants continued to apply the previous classification rule). A version of the WCST has previously been used to investigate cognitive flexibility differences between athletes and non-athletes (Taran et al., 2013).

**Statistical Power and Analyses**

We structured data analyses according to the aims of the study. We used PsyToolkit and Microsoft Excel Version 16.44 to process behavioral task data and SPSS Statistics Version 27.0 to conduct data analyses. We included data from all participants who provided accurate unique codes to associate performance on behavioral tasks with self-report questionnaire data. Prior to analyses, we identified missing data points. Less than .05% of survey item responses were missing at random; we used mean substitution based on a participant’s existing subscale responses to replace the majority of these individual missing items. Two participants did not answer an adequate number of items on the EDFLIX questionnaire to allow mean substitution. Behavioral task data was coded as missing if there was no evidence of attempts to complete the task (e.g., item response times all exceeded the time limit or “timed out”). Stop-signal task data was missing for 17 participants (5.35%), n-back task data was missing for 21 participants (6.60%), and WCST task data was missing for two participants (0.63%). Data were standardized
and univariate outliers greater than 3.0 standard deviations from their respective means (less than .01% of data points) were Winsorized to the closest values less than 3.0 standard deviations from the mean. Absolute values of skew and kurtosis for all questionnaire variables and the majority of behavioral task indices were less than 1.0, and no transformations were performed. Descriptive data for all key study variables are presented in Table 1.

We examined relationships among study variables and confirmed that multivariate analyses of variance (MANOVAs) among measure subscales and task indices were statistically appropriate. MANOVA reduces the likelihood of Type I error compared to multiple ANOVAs and takes into account relationships among dependent variables. MANOVA should only be conducted when dependent variables are related conceptually and statistically, such as when dependent variables are subscales of the same measure (Field, 2013). When reporting MANOVA results, we included Pillai’s trace test statistic as recommended by Field (2013) because it is more robust than other test statistics to violations of model assumptions. Similarly, when conducting between group post hoc tests, due to our unequal group sizes, we used the Games-Howell procedure, which is robust to violations of the homogeneity of variance assumption (Field, 2013).

**Aim 1: Differences in Emotion Regulation, Dysregulation, and Emotional States**

We conducted between-subjects univariate and multivariate ANOVAs to test the hypothesis that taekwondo athletes, compared to non-taekwondo athletes and non-athletes, would endorse: more frequent use of adaptive cognitive emotion regulation strategies and less frequent use of maladaptive cognitive emotion regulation strategies as measured by the CERQ subscales; less emotion dysregulation as measured by the DERS total score and subscales; and less recent experience of depression, anxiety, and stress as measured by the DASS-21 subscales.
To ensure adequate power to detect medium to large effects, we conducted a prior power analyses in G*Power Version 3.1.4 (Faul et al., 2007). In the analyses, we set power at .80 and \( \alpha \) at .05. When conducting a MANOVA with three groups and nine response variables of the CERQ subscales, results indicated we would need a sample size of 171 (57 per group) to detect a medium-sized effect of \( \eta^2_p = .0625 \). When conducting an ANOVA with three groups and DERS total score as the dependent variable, results indicated we would need a sample size of 159 (53 per group) to detect a medium-sized effect of \( \eta^2 = .25 \). When conducting a MANOVA with three groups and six response variables of the DERS subscales, results indicated we would need a sample size of 147 (49 per group) to detect a medium-sized effect of \( \eta^2_p = .0625 \). When conducting a MANOVA with three groups and three response variables of the DASS-21 subscales, results indicated we would need a sample size of 114 (38 per group) to detect a medium-sized effect of \( \eta^2_p = .0625 \). Our sample size surpassed these requirements with 318 total participants, the smallest group with 63 participants, indicating our analyses were adequately powered. We also examined these analyses including relevant demographic covariates.

**Aim 2: Differences in Executive Functioning**

We also conducted between-subjects MANOVAs to test the hypothesis that taekwondo athletes, compared to non-taekwondo athletes and non-athletes, would perform better at: inhibitory control using stop-signal task indices, working memory using n-back task indices, and cognitive flexibility using WCST indices. To ensure adequate power to detect medium to large effects, we conducted a prior power analyses in G*Power Version 3.1.4, setting power at .80 and \( \alpha \) at .05. Power analysis of between subjects MANOVAs with three groups and three response variables (i.e., stop-signal task indices of go trial reaction time, successful stop rate, and commission error rate; n-back task indices of total accuracy, hit accuracy, and false alarm rates;
or WCST indices of reaction time, total error rate, and perseverative error rate) indicated we would need a sample size of 114 (38 per group) to detect a medium-sized effect of $\eta^2_p = .0625$.

When conducting an ANOVA with three groups and EDFLIX total score as the dependent variable, results indicated we would need a sample size of 159 (53 per group) to detect a medium-sized effect of $\eta^2 = .25$. When conducting a MANOVA with three groups and three response variables of the EDFLIX subscales, results indicated we would need a sample size of 114 (38 per group) to detect a medium-sized effect of $\eta^2_p = .0625$. Again, our sample size was greater than required, indicating our analyses were adequately powered. We also examined these analyses including relevant demographic covariates.

**Aim 3: Relationships Among Taekwondo Athletes’ Training, Emotion Regulation, and Executive Functioning**

We conducted two-tailed correlation analyses to examine potential relationships among training variables (i.e., frequency of practice, years of practice, and experience level) and between training variables and measures of emotion regulation, dysregulation, emotional states, and executive functioning in taekwondo athletes. We conducted correlation analyses, rather than linear regression analyses, because we were interested in basic relationships among variables, and correlations are sufficient to provide this information. To ensure adequate power to detect medium to large effects, we conducted an a priori power analysis in G*Power Version 3.1.4, setting power at .80 and $\alpha$ at .05. Power analysis of a two-tailed point biserial correlation indicated we would need a total sample size of 84 to detect an effect size of $r = .30$. The study was thus underpowered for this analysis as 63 taekwondo athletes participated.
Secondary Aim 4: Impact of COVID-19 Pandemic

To explore the impact of the COVID-19 pandemic on athletes’ sports participation, we conducted two-tailed paired samples t-tests comparing both taekwondo and other athletes’ retroactively reported frequency of practice (measured as days per week) prior to March 2020 and the start of the COVID-19 pandemic with their reported frequency of practice at the time of survey completion. Using an a priori power analysis G*Power Version 3.1.4, setting power at .80 and α at .05, we found that we needed a total sample size of 34 participants to detect a moderate/medium effect size of $d = .50$. Both the taekwondo athletes and other athletes groups were greater than the required sample size, indicating our analyses were adequately powered. We also conducted initial analyses examining the percentages of taekwondo and other athletes who endorsed 1) practicing less, similarly, or more frequently (measured as hours per week); 2) feeling less close, similarly close, or closer to their team members; and 3) feeling less supported, similarly supported, or more supported by their teams since the start of the pandemic.

Results

Demographic Characteristics

Participants were 20 years old on average ($M = 19.9$ years, $SD = 2.3$), with a range of 18 to 38 years of age. See Table 2 for full sample characteristics and group statistics. Over one-third of the total sample were freshmen. Almost two-thirds reported their sex assigned at birth as female; of these, three identified as non-binary/third gender and three identified as other gender (0.94% each of the total sample). More than one-half of participants identified their race as White/Caucasian, and 17% identified their ethnicity as Hispanic/Latinx.

Looking at differences among the groups of interest to our hypotheses (see Table 2 for group difference statistics), taekwondo athletes were significantly older on average than other
athletes and non-athletes by about one year, with a small-to-medium effect size; this was consistent with taekwondo athletes’ greater likelihood of being members of higher class years in college. Other athletes, compared to taekwondo athletes and non-athletes, were significantly more likely to be male, with a relatively weak association between sex and group status. Compared to the other two groups, a smaller percentage of taekwondo athletes identified as White/Caucasian or as Black/African American and a larger percentage identified as Asian; however, the statistical significance of these differences could not be calculated due to the multiple response set nature of the race variable (i.e., participants were able to select multiple race categories violating the assumption of independent responses). Taekwondo athletes were also significantly less likely to identify as Hispanic/Latinx than other athletes and non-athletes; this association between ethnicity and group status was weak.

Regarding sports-related characteristics, taekwondo athletes reported training for a median length of 3-4 years, with nine athletes (14.29%) training for more than 10 years. More than one-third (n = 25; 39.68%) were black belts, meaning that they had achieved a senior rank in the martial art at the time of survey completion. They reported currently training with an average team size of nine members (M = 9.5, SD = 8.0, range = 0-30). At the time of study completion, the plurality were training using a combination of in-person and virtual modalities (n = 26; 41.27%), with the rest training exclusively virtually (n = 15; 23.81%), only in-person (n = 11; 17.46%), or not currently training with their team (n = 11; 17.46%). Approximately one-third reported living on-campus (n = 24; 38.10%), one-third off campus in the surrounding area (n = 24; 38.10%), and the remainder in-state outside of the surrounding area (n = 7; 11.11%) or out of state (n = 8; 12.70%). Approximately one-quarter (n = 17; 26.98%) reported participating in other sports, in addition to taekwondo.
Participants in the group of other (i.e., non-taekwondo) athletes reported participating in 24 different primary sports, with the most common being basketball \( (n = 19) \), soccer \( (n = 13) \), and lacrosse \( (n = 11) \). More than one-third \( (n = 39; 40.63\%) \) reported participating in other sports, in addition to their identified primary sport. Approximately one-third \( (n = 36; 37.50\%) \) had trained in their primary sport for more than 10 years, with the median length of training being 7-8 years. About one-half trained individually \( (n = 20; 20.83\%) \) or with others without being part of a team/club \( (n = 26; 27.08\%) \). Of the remaining 50 athletes, 22 \( (44.00\%) \) were members of varsity teams, 14 \( (28.00\%) \) were members of university club teams, and 14 \( (28.00\%) \) were members of private clubs not affiliated with their university. The athletes who were part of a club/team reported currently training with an average team size of 16 members \( (M = 15.96, SD = 14.82, \text{range} = 0-52) \). The majority were training in-person \( (n = 31; 62.00\%) \), with the rest training virtually \( (n = 3; 6.00\%) \), training using a combination of both modalities \( (n = 4; 8.00\%) \), or not currently training with their team \( (n = 12; 24.00\%) \). Approximately one-third reported living on-campus \( (n = 36; 37.50\%) \), one-third off campus in the surrounding area \( (n = 30; 31.25\%) \), and one-third off campus in-state outside of the surrounding area \( (n = 30; 31.25\%) \).

**Correlation Analyses Among Variables of Interest**

To better understand our data and to confirm that conducting separate MANOVAs among measure subscales and task indices was statistically indicated, we examined relationships among emotion regulation and executive functioning variables through correlation analyses.

**Relationships Among Emotion Regulation Measures**

Correlation analyses examined relationships among use of emotion regulation strategies, emotion regulation difficulties, and emotional states (see Table 3). The majority of CERQ subscales were moderately positively correlated with one another \( (r's \text{ between .11 and .77, } p's < 0.05) \).
there was only one significant negative, weak correlation between catastrophizing and positive reappraisal ($r = -.16, p = .005$). Similarly, the majority of DERS subscales were moderately positively correlated with one another ($r$’s between .12 and .77, $p$’s < .05) and strongly positively correlated with the total DERS score ($r$’s between .40 and .91, $p$’s < .001). Emotional states of depression, anxiety, and stress were strongly, positively correlated ($r$’s = .72 to .79, $p$’s < .001).

Regarding correlations among different measures, DERS total score was significantly positively correlated with strategies of self-blame, rumination, catastrophizing, and other-blame ($r$’s = .39, .34, .49, and .21, respectively; $p$’s < .001); significantly negatively correlated with positive refocusing, refocus on planning, positive reappraisal, and putting into perspective ($r$’s = -.23, -.41, -.48, and -.23, respectively; $p$’s < .001); and not significantly correlated with acceptance. DERS subscale scores and DASS-21 subscale scores generally followed this pattern of correlations with CERQ subscale scores with smaller associations (absolute value of $r$’s between .12 and .57, $p$’s < .05). DERS total score was also positively strongly correlated with DASS-21 depression, anxiety, and stress subscales ($r$’s = .62, .56, and .62, respectively; $p$’s < .001). DASS-21 subscales were generally positively correlated with the DERS subscales in the following ways: small associations with lack of emotional awareness; medium associations with nonacceptance of emotional responses, difficulty engaging in goal-directed behavior, and lack of emotional clarity; and large associations with impulse control difficulties and limited access to emotion regulation strategies. These statistical correlations, in addition to the conceptual relations, supported conducting separate MANOVAs to test between-group differences in CERQ subscales, DERS subscales, and DASS-21 subscales.
**Relationships Among Executive Function Indices**

Correlation analyses also examined relationships among inhibitory control, working memory, and cognitive flexibility indices, including the self-report EDFLIX measure of cognitive flexibility (see Table 4). For the stop-signal task outcome variables, there was a significant positive correlation between successful stop rate and go trial reaction time ($r = .36$, $p < .001$) and a significant negative correlation between successful stop rate and commission error rate ($r = -.57$, $p < .001$). For the n-back task outcome variables, there were significant large correlations between total accuracy and hit accuracy rates ($r = .69$, $p < .001$) and between total accuracy and false alarm rates ($r = -.73$, $p < .001$). There were no significant correlations between stop-signal and n-back task variables. The three WCST outcome variables were all positively correlated ($r$’s between .39 and .87, $p$’s < .001). WCST reaction time and total error rate were also positively correlated with stop-signal stop rate, though the effect sizes were small ($r$’s = .13 and .14, respectively; $p$’s < .05). All WCST indices were moderately correlated with all n-back indices, such that better performance on the WCST was related to better performance on the n-back task. For example, WCST total error rate (for which higher values indicate worse performance) was negatively correlated with n-back accuracy rates (for which higher values indicate better performance) and positively correlated with n-back false alarm rate (for which higher values indicate worse performance). The discussed statistical correlations, in addition to conceptual relations, supported conducting separate MANOVAs to determine between-group differences in scores on the stop-signal, n-back, and WCST tasks.

Additionally, the EDFLIX subscales were all positively and strongly correlated with total EDFLIX score ($r$’s between .68 and .83, $p$’s < .001) and positively and moderately correlated with each other ($r$’s between .30 and .39, $p$’s < .001). The general flexibility subscale was only
weakly positively correlated with n-back total accuracy ($r = .13, p = .03$) and not significantly associated with any of the stop-signal or WCST indices. Though relationships involving the other EDFLIX subscales were not specifically part of this project’s hypotheses, we included them in correlation analyses with the executive function measures to determine if further analyses or future investigations were warranted. There were small negative correlations between the EDFLIX total score and WCST total error rate ($r = -.17, p = .003$) and perseverative error rate ($r = -.13, p = .02$; the food/exercise flexibility subscale also followed this pattern ($r = -.26$ and -.23, respectively; $p$’s < .001). EDFLIX total, food/exercise, and weight/shape subscales were also correlated with the majority of n-back indices, such that higher self-reported cognitive flexibility was associated with improved performance on the working memory task, though effect sizes were small ($r$’s between -.14 and .22, $p$’s < .05).

**Relationships Between Emotion and Cognitive Variables**

Few relationships were found between emotion variables and cognitive variables, and nearly all significant correlations were small. Specifically, stop-signal task indices were not significantly correlated with any CERQ, DERS, or DASS-21 subscales. Similarly, WCST indices were not significantly correlated with any of the DERS or DASS-21 subscales; only the CERQ catastrophizing subscale was weakly correlated with total error rate ($r = .14, p = .02$) and perseverative error rate ($r = .12, p = .03$). N-back task indices were weakly correlated with several measure subscales. N-back total accuracy rate was negatively correlated with CERQ positive refocusing, catastrophizing, and other blame subscales; DERS total, impulse control difficulties, and limited access to emotion regulation strategies scores; and DASS-21 depression and anxiety scores (all $r$’s between -.12 and -.26, $p$’s < .05). Similarly, n-back hit accuracy rate was negatively correlated with catastrophizing, other-blame, impulse control difficulties, and
anxiety scores (all $r$’s between -.13 and -.19, $p$’s < .05). N-back false alarm rate was positively correlated with positive refocusing, catastrophizing, other-blame, impulse control difficulties, limited access to emotion regulation strategies, and anxiety scores (all $r$’s between .12 and .21, $p$’s < .05). See Table 5 for summary of significant correlations between emotion-related variables and cognitive task indices.

General flexibility was a notable exception, with the EDFLIX subscale score significantly correlated with nearly all CERQ (small effect sizes, absolute value of $r$’s between .11 and .42, $p$’s < .05), DERS (medium to large effect sizes, $r$’s between -.22 and -.64, $p$’s < .001), and DASS subscales (medium effect sizes, $r$’s between -.43 and -.46, $p$’s < .001). These correlations were all negative, with the exception of positive correlations with the CERQ subscales of refocus on positive refocusing, refocus on planning, positive reappraisal, and putting into perspective (see last row of Table 3).

**Differences in Emotion Regulation, Dysregulation, Depression, Anxiety, and Stress**

A series of MANOVAs examined differences in: 1) use of emotion regulation strategies, 2) dysregulation/difficulties in emotion regulation, and 3) experience of depression, anxiety, and stress among the three study groups. These analyses were also run separately with age, sex, ethnicity, and race as covariates. The vast majority of results did not meaningfully change, so results presented here do not include covariates to preserve degrees of freedom; see footnotes for more information. There was a statistically significant multivariate main effect of athlete status (i.e., taekwondo athlete, other athlete, non-athlete) on emotion regulation as measured with the CERQ subscales, $F(18,616) = 3.19, p < .001$, Pillai’s trace = .17, $\eta_p^2 = .09$. There were significant between-group differences in catastrophizing, $F(2,315) = 6.66, p = .001$, $\eta_p^2 = .04$, such that taekwondo athletes endorsed less frequent use of catastrophizing than both other
athletes (post hoc \( p = .02 \)) and non-athletes (post hoc \( p < .001 \)). See Table 6 for group means and statistics. There was also a significant between-group difference in rumination, such that other athletes endorsed significantly less frequent use of rumination than non-athletes (post hoc \( p < .001 \)). Finally, there was a significant between-group difference in positive refocusing, such that other athletes endorsed more frequent use of positive refocusing than taekwondo athletes (post hoc \( p = .01 \)).

There was also a statistically significant difference between groups on DERS total score as determined by a one-way univariate ANOVA, \( F(2,315) = 3.49, p = .03, \eta^2 = .02 \), such that other athletes endorsed significantly fewer difficulties with emotion regulation than non-athletes (post hoc \( p = .03 \)).\(^1\) Using MANOVA, there was a multivariate main effect of athlete status on emotion dysregulation as measured with the DERS subscales, \( F(12,622) = 4.82, p < .001 \), Pillai’s trace = .17, \( \eta_p^2 = .09 \). There was a significant between-group difference in impulse control difficulties, such that taekwondo athletes endorsed fewer difficulties than non-athletes (post hoc \( p = .006 \)). There were also significant between-group differences in limited access to emotion regulation strategies, such that both taekwondo athletes and other athletes endorsed less limited (i.e., better) access to strategies than non-athletes (post hoc \( p = .02 \) and \( p = .02 \), respectively). Similarly, there were significant between-group differences in lack of emotional clarity, such that both taekwondo and other athletes endorsed less lack of (i.e., better) clarity than non-athletes (post hoc \( p = .03 \) and \( p < .001 \), respectively).

Finally, there was a statistically significant multivariate main effect of athlete status on emotional states as measured with the DASS-21, \( F(6, 628) = 4.92, p < .001 \), Pillai’s trace = .09,

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\(^1\) When including sex and race as covariates, the between group difference in positive refocusing was no longer significant.

\(^2\) When running ANCOVA with DERS total as the outcome variable and sex as a covariate, there was no longer a significant difference between groups, \( F(2,314) = 2.24, p = .11, \eta^2 = .01 \).
η_p^2 = .05. There were significant between-group differences in depression, such that taekwondo athletes and other athletes endorsed fewer symptoms of depression than non-athletes (post hoc \( p < .05 \) and \( p < .001 \), respectively). Similarly, there were between-group differences in anxiety, such that taekwondo athletes and other athletes endorsed fewer symptoms of anxiety than non-athletes (post hoc \( p < .001 \) and \( p = .01 \), respectively). Stress displayed the same general pattern of athletes (both taekwondo and non-taekwondo) endorsing fewer stress symptoms compared to non-athletes, though the differences were not statistically significant.

**Differences in Executive Functioning**

As mentioned, significant correlations among task indices suggested separate MANOVAs were appropriate for each behavioral task. There was no significant effect of athlete status on inhibitory control as measured with stop-signal task indices, \( F(6, 594) = .68, p = .67, \eta_p^2 = .01 \). See Table 7 for group means and statistics.

There was a statistically significant multivariate main effect of athlete status on working memory as measured with n-back task indices, \( F(6,586) = 5.43, p < .001 \), Pillai’s trace = .11, \( \eta_p^2 = .05 \). There were significant between-group differences in n-back total accuracy, hit accuracy, and false alarm rates, such that taekwondo athletes performed better than other athletes and non-athletes on all indices (post hoc \( p \)’s <.001).

There was also a statistically significant multivariate main effect of athlete status on cognitive flexibility as measured with WCST indices, \( F(6,624) = 7.97, p < .001 \), Pillai’s trace = .14, \( \eta_p^2 = .07 \). There were significant between-group differences in WCST reaction time, total error rate, and perseverative error rate, such that taekwondo athletes performed better than other athletes and non-athletes on all indices (\( p \)’s <.001).
Finally, there was a statistically significant difference between groups on EDFLIX total score as determined by a one-way univariate ANOVA, $F(2,313) = 5.52, p = .004, \eta^2 = .03$, such that taekwondo athletes endorsed greater overall cognitive flexibility than other athletes (post hoc $p = .007$) and non-athletes (post hoc $p = .004$). Using MANOVA, there was a multivariate main effect of athlete status on cognitive flexibility as measured with the EDFLIX subscales, $F(6, 624) = 6.65, p < .001$, Pillai’s trace $= .12, \eta_p^2 = .06$. There were significant between-group differences in food and exercise flexibility, such that taekwondo athletes endorsed greater flexibility than other athletes ($p < .001$) and non-athletes ($p = .01$) and non-athletes endorsed greater flexibility than other athletes (post hoc $p = .004$). There was also a significant between-group difference in weight and shape flexibility, such that taekwondo athletes endorsed greater flexibility than non-athletes ($p = .02$). Taekwondo athletes also endorsed greater general flexibility than other athletes and non-athletes, though the differences were not statistically significant.

**Taekwondo Athletes’ Training, Emotion Regulation, and Executive Functioning**

In taekwondo athletes, correlation analyses examined relationships among training indices (i.e., frequency of practice, years of practice, and experience level) and emotion regulation measures, emotional states, and performance on executive functioning tasks. Given that the current COVID-19 pandemic likely impacted training frequency, both current (i.e., at the time of survey completion) and pre-pandemic (i.e., prior to March 2020) frequency measures were used in analyses. These measures of pre-March 2020 hours per week, pre-March 2020 days per week, current hours per week, and current days per week of training were all highly correlated ($r$’s = .50 to .86, $p$’s < .001; see Table 8). Years of training was not significantly correlated.

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3 Adding age, sex, race, and ethnicity as covariates did not meaningfully change results, with the exception of the CERQ positive refocusing and DERS total score outcomes mentioned above.
correlated with any of these training frequency indices. Belt rank was moderately correlated with pre-March 2020 hours per week \( (r = .27, p = .05) \) and days per week of training \( (r = .34, p = .01) \) and strongly correlated with years of training \( (r = .88, p < .001) \).

Taekwondo training indices were not statistically correlated with the majority of emotion regulation or emotional states measures, with the following exceptions. Pre-March 2020 days per week of training was negatively correlated with the CERQ acceptance \( (r = -.29, p = .03) \) and catastrophizing subscales \( (r = -.41, p < .001) \). Current weekly hours and days spent training were negatively correlated with the CERQ catastrophizing subscale \( (r = -.25, p < .05; r = -.33, p = .01, \text{ respectively}) \); DERS total \( (r = -.26, p = .04; r = -.30, p = .02, \text{ respectively}) \), difficulty engaging in goal-directed behavior \( (r = -.25, p < .05; r = -.32, p = .01, \text{ respectively}) \), and limited access to emotion regulation strategies \( (r = -.31, p = .01; r = -.35, p = .01, \text{ respectively}) \); and DASS-21 depression subscale \( (r = -.29, p = .03; r = -.29, p = .02, \text{ respectively}) \). Current weekly days spent training was also negatively correlated with impulse control difficulties \( (r = -.31, p = .01) \). This meant that frequency of training at the time of survey completion was associated with fewer emotion regulation difficulties and less endorsement of depression symptoms. Belt rank was negatively correlated with the CERQ catastrophizing subscale \( (r = -.25, p = .05) \), DASS-21 anxiety subscale \( (r = -.30, p = .02) \), and DASS-21 stress subscale \( (r = -.27, p = .03) \). See Table 8 for all correlations between training indices and key study variables.

With regard to measures of executive functioning, both pre-March 2020 and current taekwondo training frequency indices were positively correlated with the EDFLIX total and general flexibility subscales with medium to large effect sizes \( (r’s = .29 \text{ to } .50, p’s < .05; \text{ see Table 8}) \), suggesting frequency of training was associated with greater self-reported cognitive flexibility. Pre-March 2020 days per week of training was also positively moderately correlated
with food/exercise flexibility \( (r = .30, p = .03) \). The only significant correlation between any of the training indices and behavioral task measures was a moderate negative correlation between belt rank and false-alarm rate on the n-back task \( (r = -.33, p = .01) \). When conducting univariate and multivariate ANOVAs on the key study variables using belt rank as a categorical variable (i.e., categories of beginner, intermediate, and advanced), there were no significant main effects on key study variables.

**Impact of the COVID-19 Pandemic on Athletic Participation and Perceived Benefits**

Ten taekwondo athletes and seven other athletes began participating in their sport after the start of the pandemic and, so, are not included in the following analyses. Both taekwondo athletes and other athletes reported practicing significantly less often since the start of the COVID-19 pandemic. Taekwondo athletes reported practicing an average of 3.64 days per week prior to March 2020 and 2.17 days per week at the time of survey response, \( t(52) = 7.76, p < .001, d = 1.07 \). Additionally, the vast majority of taekwondo athletes \( (n = 47; 88.70\%) \) reported practicing fewer hours per week currently. Other athletes reported practicing an average of 4.81 days per week prior to March 2020 and 3.48 days per week at the time of survey response, \( t(88) = 6.87, p < .001, d = .73 \), and a majority \( (n = 51; 57.30\%) \) reported practicing fewer hours per week currently.

When asked whether they felt less close, similarly close, or closer to their team members, most taekwondo athletes \( (n = 37; 69.81\%) \) reported feeling less close. However, when asked whether they felt less, similarly, or more supported by their team, most taekwondo athletes \( (n = 29; 54.72\%) \) reported feeling similarly supported. Some reported feeling more supported \( (n = 8; 15.09\%) \), one participant declined to answer, and the remainder reported feeling less supported \( (n = 16; 30.19\%) \). Of the other athletes who indicated participating in team sports, most \( (n = 29; \)
60.42% also reported feeling less close to their team members. Relatively similar percentages reported they felt less supported ($n = 18; 37.50\%$), similarly supported ($n = 16; 33.33\%$), and more supported by their team ($n = 13; 27.08\%$) since the start of the pandemic.

**Discussion**

Emotion regulation and executive functioning are important affective and cognitive processes which significantly influence well-being. Regular mindful exercise, such as taekwondo, may be a particularly beneficial modality by which to strengthen these capabilities. To investigate this possibility, this study examined emotion regulation and executive functioning differences among collegiate taekwondo practitioners, non-taekwondo athletes, and non-athletes.

**Hypothesis 1**

The first aim of this study was to examine between-group differences in emotion regulation, emotion dysregulation, and recent experiences of emotional states among collegiate taekwondo student athletes, other non-taekwondo athletes, and non-athletes. Given that taekwondo directly addresses skills thought to strengthen emotion regulation capacities, we hypothesized that taekwondo athletes, compared to other athletes and non-athletes, would endorse more frequent use of adaptive emotion regulation strategies, less frequent use of maladaptive emotion regulation strategies, fewer difficulties in emotion regulation, and less recent experience of depression, anxiety, and stress. Results partially supported this hypothesis. Specifically, taekwondo athletes endorsed less frequent use of catastrophizing than other athletes and non-athletes and fewer impulse control difficulties, better access to emotion regulation strategies, better emotional clarity, and fewer recent depression and anxiety symptoms than non-athletes.
Catastrophizing was the only cognitive emotion regulation strategy for which results supported our hypothesis (i.e., taekwondo athletes endorsed less use of this putatively maladaptive strategy than both of the other groups). Other (i.e., non-taekwondo) athletes endorsed less frequent use of rumination than non-athletes, which suggests a positive effect of general sports participation on emotion regulation. Surprisingly, and contradictory to our hypothesis, other athletes endorsed more frequent use of positive refocusing than taekwondo athletes (though this difference did not remain significant when including sex and race as covariates). Whereas catastrophizing was the only cognitive emotion regulation strategy for which results supported the hypothesis, it may be a particularly important strategy. Studies have consistently shown use of catastrophizing to be one of the most stable strategy predictors of psychopathology, particularly depression and anxiety (Garnefski & Kraaij, 2007; Garnefski et al., 2001; Potthoff et al., 2016). Other stable strategy predictors tend to be rumination, self-blame, and positive reappraisal. Indeed, in the current study, catastrophizing was the cognitive emotion regulation strategy most strongly correlated with reported symptoms of depression, anxiety, and stress, followed by the strategies of positive reappraisal, self-blame, and rumination.

Regarding dysregulation, both athlete groups endorsed fewer difficulties in accessing emotion regulation strategies and in emotional clarity than non-athletes, but only taekwondo athletes endorsed fewer impulse control difficulties than non-athletes. Notably, limited access to emotion regulation strategies and impulse control difficulties were the measures of dysregulation most strongly correlated with symptoms of depression, anxiety, and stress. Other athletes endorsed fewer total difficulties with emotion regulation than non-athletes, which again suggests positive benefits of sports participation on emotion regulation in general (though this difference did not remain significant when including sex as a covariate). Moreover, both athlete groups
endorsed fewer symptoms of depression and anxiety than non-athletes, further providing support for positive benefits of exercise on mood, potentially through improved emotion regulation.

**Hypothesis 2**

The second aim of this study was to examine between-group differences in executive functioning among taekwondo athletes, other athletes, and non-athletes. We hypothesized that taekwondo athletes, compared to other athletes and non-athletes, would perform better on tasks measuring inhibitory control, working memory, and cognitive flexibility. Results generally supported this hypothesis. Specifically, taekwondo athletes performed significantly better than other athletes and non-athletes on all task indices assessing working memory and cognitive flexibility. Additionally, taekwondo athletes self-reported greater overall cognitive flexibility than both other groups. Notably, performance on the majority of working memory and cognitive flexibility indices was weakly but significantly and negatively associated with use of catastrophizing. In other words, worse executive functioning was related to increased use of catastrophizing, which was also related to anxiety, depression, and stress. Performance on working memory indices was also negatively related to use of other-blame, total difficulties regulating emotion, impulse control difficulties, limited access to regulation strategies, depression, anxiety, and, surprisingly, positive refocusing.

**Hypothesis 3**

The third aim of this study was to determine whether, within the group of taekwondo athletes, a “dose-response” curve exists between years of practice, frequency of practice, and/or experience level and emotion regulation and executive functioning. We hypothesized that taekwondo engagement and experience would be related to more frequent use of adaptive emotion regulation strategies, less frequent use of maladaptive emotion regulation strategies,
fewer difficulties in emotion regulation, less emotional distress, and better performance on tasks of executive functioning. Results partially supported this hypothesis. Specifically, greater taekwondo engagement (i.e., greater frequency of training) at the time of survey completion was related to less frequent use of catastrophizing, fewer emotion regulation difficulties, and fewer depression symptoms. Additionally, more taekwondo experience (i.e., higher belt rank) was related to less frequent use of catastrophizing, fewer anxiety symptoms, and fewer stress symptoms. Greater frequency of training was also related to greater self-reported cognitive flexibility. Taekwondo experience was unrelated to task performance, except that higher belt rank was related to fewer working memory task commission errors.

Hypothesis 4

A secondary aim of this study was to explore the impact the COVID-19 pandemic had on athletes’ sports participation and their perceived benefits of sports club or team membership. We hypothesized that athletes, both taekwondo and non-taekwondo, would endorse less frequent participation in their primary sport, perceive themselves as less close to their team members, and perceive themselves as less supported by their teams at the time of study completion, compared to prior to the pandemic and physical distancing restrictions. Results mostly supported this hypothesis. Since the start of the pandemic, both taekwondo athletes and other athletes endorsed practicing significantly less often, and a majority of both groups reported feeling less close to their team members. However, only a small plurality of other athletes reported feeling less supported by their teams, and the majority of taekwondo athletes reported feeling similarly supported by their teams.

In sum, athletes (both taekwondo and non-taekwondo), compared to non-athletes, endorsed better access to emotion regulation strategies, better emotional clarity, and less recent
experience of depression and anxiety symptoms. Engagement in taekwondo was related to several benefits beyond that of athletic engagement more broadly. Specifically, taekwondo athletes performed better on working memory and cognitive flexibility tasks and endorsed greater cognitive flexibility, less use of catastrophizing, and fewer impulse control difficulties. Notably, these indices for which taekwondo participants displayed a unique advantage were associated with fewer depression, anxiety, and stress symptoms across the sample. Moreover, greater engagement and/or experience in taekwondo was related to less frequent use of catastrophizing, fewer emotion regulation difficulties, greater self-reported cognitive flexibility, fewer working memory task commission errors, and less recent experience of depression, anxiety, and stress. These findings support overall emotion regulation benefits of athletic engagement, as well as specific emotion regulation and executive functioning benefits of taekwondo.

**Study Strengths**

The present study had several noteworthy strengths. First, the study investigated potential benefits of a popular mindful exercise – taekwondo. Taekwondo’s global popularity suggests some facets of the martial art are widely appealing, and previous studies have demonstrated positive associations between taekwondo and physical health (see Fong & Ng, 2011 for a review). Therefore, if found to benefit emotional and cognitive well-being, taekwondo may be a particularly palatable modality of prevention and/or intervention.

Second, the study examined both emotion regulation and executive functioning as primary variables of interest. Emotion regulation and executive functioning are critical, complex, related processes that are not fully understood and are often examined separately; this study examined them concurrently and provided evidence regarding the nature of their relationship.
The study also examined these primary variables of interest using multiple measures and methods, specifically self-report questionnaires and behavioral task performance.

Additionally, this study focused on a novel population of collegiate taekwondo practitioners in the United States. Initial investigations of taekwondo’s psychological benefits have been conducted primarily with school-age children (Cho, Kim, & Roh, 2017; Cho, So, & Roh, 2017; Lakes et al., 2013) and/or in other countries (e.g., South Korea; Cho, Kim, & Roh, 2017; Cho, So, & Roh, 2017; Kim, 2015; Pons van Dijk et al., 2013; Toskovic, 2001). Emerging adults are at relatively high risk for psychopathologies associated with deficits in emotion regulation (e.g., depression, anxiety, substance use, eating disorders; Kessler et al., 2005). Hence, investigating taekwondo as an alternative prevention and/or intervention modality, compared to traditional psychotherapies, is especially relevant in this age group. We also included two comparison groups – non-taekwondo athletes and non-athletes – to gain understanding about how benefits of taekwondo may align with or differ from those of other sports. Finally, we recruited a large enough sample that the majority of our analyses were adequately powered.

**Study Limitations**

There were also several limitations to the present study. Most notably, this was a cross-sectional study, so we were unable to determine causality in the associations between the variables of interest. This was an initial investigation into emotional, cognitive, and psychological benefits of taekwondo, so comparing these constructs among already existing groups of taekwondo athletes, other athletes, and non-athletes was appropriate. However, the groups were self-selected, not randomly assigned. Individuals with better baseline regulatory abilities may be more likely to participate in sports or mindful exercise such as taekwondo, to be more engaged, or to pursue participation to higher levels. There may also be a positive feedback
loop, whereby high-regulatory individuals are more likely to engage in the sport, and this engagement then further improves emotion regulation and executive functioning. It is impossible to know the sequential manner in which variables affect each other without a longitudinal component, which should be the focus of future research.

Additionally, there were several measurement-related limitations to this study. We assessed emotion regulation and emotional states via self-report which, while consistent with similar studies, is subject to social desirability bias and to bias secondary to deficits in introspective ability. Notably, we used several indices to measure engagement and experience in sports (e.g., frequency of practice, length of time training in sport, competitive level, belt rank attained in taekwondo); however, these were also collected via self-report, and thus subject to the same limitations. Moreover, there is no consensus of what defines an “athlete.” We provided a binary definition of athlete (i.e., “an individual who trains and/or competes in an identified sport individually or as part of a club/team”) that we used to assign individuals to the primary comparison groups, but other individuals or studies may define athlete status differently. We also did not assess the personal significance of participants’ athlete identity or the motivations contributing to their sports engagement.

We assessed one executive functioning ability (i.e., cognitive flexibility) via multiple measurement approaches (i.e., task performance and self-report), but we only assessed inhibitory control and working memory via performance on one task each. These tasks were performed remotely, without the direct supervision of the researchers, which likely increased overall participation rate; however, researchers were unable to ensure participants actively participated in these tasks or were motivated to perform well on them. Several participants who clearly refrained from engaging in these tasks, as observable via measurement indices such as “timed
out” reaction times and incorrect responses on all trials, were excluded from related analyses. Furthermore, due to a technological limitation involving the manner in which PsyToolkit displayed participants’ stop-signal task data, we were unable to calculate stop-signal reaction time. Whereas we did include other indices of stop-signal task performance, stop-signal reaction time is a primary index of inhibitory control that is missing from this dataset (Logan & Cowan, 1984).

The majority of our analyses were adequately powered; however, the analysis investigating our third hypothesis was not. Our sample was also composed primarily of participants enrolled in colleges in the northeast, which may limit generalizability of our findings to other populations. Additionally, taekwondo participants were recruited differently and compensated differently than participants in the other two groups, which may have differentially impacted different group’s participants’ motivation or engagement in the study; however, all participation was voluntary and compensation was not performance-based. Finally, this study was completed during the COVID-19 pandemic. The pandemic directly impacted college students and college sports participation in several ways. Due to physical distancing and gathering size restrictions, colleges and universities transitioned to remote learning and temporarily suspended sports participation. We collected data approximately one year after the start of the pandemic, at which time learning modality and sports participation varied greatly by institution and individual preference. In other words, some participants were living on campus and attending sports practices in-person, others were living off campus and attending practices virtually or not attending, and still others were engaging in a hybrid model of training. Moreover, pandemic-related stressors may have impacted participants’ use of emotion regulation strategies, difficulties with emotion regulation, and especially recent emotional states; we cannot be certain
measurement of these variables at the time of data collection would generalize to other non-pandemic times.

Finally, the taekwondo athlete population included here were specifically college athletes. Practicing taekwondo as part of a college club may be somewhat different than training in the martial art outside of the college context. Most notably, the focus on competition may be different. The taekwondo athletes included here belonged to clubs that participate in regional competitive leagues. Whereas this allows for suitable comparisons with other collegiate athletes, club participation in competitive leagues may suggest that college taekwondo clubs include less, or focus less explicitly on, the more mindful components of taekwondo (e.g., meditation, breathing) than non-college or non-competitive training schools. Our overall framework suggests that participation in non-college taekwondo, if associated with increased practice of mindful components, may actually increase the emotional, cognitive, and psychological benefits of participation. However, it also means our findings may not be generalizable to practice of taekwondo in non-college contexts.

**Conclusions, Implications, and Future Directions**

The results of this study contribute meaningfully to the body of knowledge and literature on benefits of mindful exercise. Findings provide support for several emotion regulation and executive functioning benefits of taekwondo, including some that appear unique to the sport as compared to other forms of athletic engagement. Specifically, taekwondo participation appears related to less frequent use of catastrophizing, fewer impulse control difficulties, improved working memory, and improved cognitive flexibility than participation in other sports or no sports. Additionally, the results provide overall support for emotional, cognitive, and psychological benefits of sports participation in general. Specifically, participation in sports
(both taekwondo and non-taekwondo sports) appears related to fewer emotion regulation difficulties, fewer depression symptoms, and fewer anxiety symptoms than non-participation. Finally, increased engagement and experience in taekwondo may strengthen its benefits, as greater frequency of training and/or higher experience level were related to less frequent use of catastrophizing, fewer emotion regulation difficulties, better working memory task performance, greater cognitive flexibility, and fewer depression, anxiety, and stress symptoms.

However, the results also highlight the need for further investigation into the benefits of taekwondo and other forms of mindful exercise, as well as the mechanisms or interactions underlying these benefits. Future studies should include multiple methods of data collection, such as self- and other-report (e.g., parent-report or peer-report) of emotion regulation, as well as self-report and behavioral task performance of executive functioning. The importance of this is highlighted by our study’s findings that self-reported cognitive flexibility was weakly related to cognitive flexibility task performance and that taekwondo athletes both reported and demonstrated greater cognitive flexibility compared to the other two groups but that level of engagement and experience in taekwondo was only related to self-reported cognitive flexibility (not task performance). Additionally, future studies should include measures of both hot and cool executive functions. Hot executive functions refer to self-management skills used in motivationally significant affective situations where emotions run high, whereas cool executive functions refer to skills used under relatively non-affective conditions. The majority of studies of executive functioning in the sports context focus on cool executive functions; hot executive functions are only beginning to receive attention (Holfelder et al., 2020).

Future studies should also include populations from different age groups, geographic regions, and timeframes (e.g., not during a global pandemic) as these sample characteristics may
interact with or differentially impact the variables of interest. Whereas the majority of analyses in this study were adequately powered, future studies should recruit larger sample sizes (specifically of taekwondo and non-taekwondo athletes) to allow 1) more in-depth analysis of the influence of engagement, duration, and experience level of taekwondo training on emotion regulation and executive functioning and 2) comparison with other specific sports, rather than all non-taekwondo sports grouped together. It would also be helpful to assess motivation of sports and mindful exercise participation, as well as athlete identity, in future studies. Established measures to assess these constructs include the Athletic Identity Measurement Scale (Brewer et al., 1993) and the Sport Commitment Questionnaire -2 (Scanlon et al., 2016). Finally, and perhaps most importantly, longitudinal studies of taekwondo participation are necessary to address questions of causality and to, if indicated, develop targeted taekwondo-based interventions to improve emotion regulation and executive functioning in healthy and clinical populations. With better information about temporal precedence, researchers can examine more thorough and complex models. For instance, the literature reviewed above suggests that mindful exercise may improve emotion regulation by way of improving executive functioning. Researchers could only truly find support for this overall mediation framework with information about causality.
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**Table 1**

*Psychometric Properties for Emotion Regulation Measures and Executive Functioning Tasks*

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<th>Measure/Task</th>
<th>M</th>
<th>SD</th>
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<th>Actual Range</th>
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*Note.* CERQ = Cognitive Emotion Regulation Questionnaire; DERS = Difficulties in Emotion Regulation Scale; DASS = Depression Anxiety Stress Scales; EDFLIX = Eating Disorder Flexibility Index; ms = milliseconds.
Table 2

**Demographic Characteristics of Taekwondo Athletes, Other Athletes, and Non-athletes**

<table>
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<tr>
<th>Characteristic</th>
<th>Total Sample (N = 318)</th>
<th>Taekwondo Athletes (n = 63)</th>
<th>Other Athletes (n = 96)</th>
<th>Non-athletes (n = 159)</th>
<th>Statistics</th>
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<tr>
<td>------------------------------</td>
<td></td>
<td>% (n) or M (SD)</td>
<td>% (n) or M (SD)</td>
<td>% (n) or M (SD)</td>
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<tr>
<td>Age (years)</td>
<td>19.93 (2.29)</td>
<td>20.79 (2.44)</td>
<td>19.61 (2.61)</td>
<td>19.79 (1.94)</td>
<td>$F(2,315) = 5.86,\ p = .003, \eta^2 = .04$</td>
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<td>Sex (female)</td>
<td>60.69% (193)</td>
<td>76.19% (48)</td>
<td>36.46% (35)</td>
<td>69.18% (110)</td>
<td>$X^2 (2, N = 318) = 34.78,\ p &lt; .001, V = .33$</td>
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<td>White/Caucasian</td>
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<td>47.62% (30)</td>
<td>67.71% (65)</td>
<td>55.35% (88)</td>
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<td>Black/African American</td>
<td>22.33% (71)</td>
<td>4.76% (3)</td>
<td>23.96% (23)</td>
<td>28.30% (45)</td>
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<tr>
<td>Asian</td>
<td>17.30% (55)</td>
<td>49.21% (31)</td>
<td>4.17% (4)</td>
<td>12.58% (20)</td>
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<tr>
<td>American Indian/Alaska Native</td>
<td>0.63% (2)</td>
<td>3.17% (2)</td>
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<tr>
<td>Native Hawaiian/ Pacific Islander</td>
<td>1.26% (4)</td>
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<td>2.08% (2)</td>
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<tr>
<td>Other</td>
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<td>4.76% (3)</td>
<td>8.33% (8)</td>
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<tr>
<td>Ethnicity (Hispanic/Latinx)</td>
<td>16.98% (54)</td>
<td>6.35% (4)</td>
<td>19.79% (19)</td>
<td>19.50% (31)</td>
<td>$X^2 (2, N = 318) = 6.30,\ p = .04, V = .14$</td>
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<tr>
<td>Freshman</td>
<td>38.99% (124)</td>
<td>14.29% (9)</td>
<td>53.13% (51)</td>
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<tr>
<td>Sophomore</td>
<td>22.64% (72)</td>
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<td>19.05% (12)</td>
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*Note.* Chi-squared could not be calculated for Race due to the multiple response set nature of the variable.
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<td>20. General</td>
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<td>-.45^</td>
</tr>
</tbody>
</table>

**Note.** DERS = Difficulties in Emotion Regulation Scale.

*p < .05. ^p < .001.
Table 4

Correlations Among Executive Functioning Indices

<table>
<thead>
<tr>
<th>Task Index/Measure Subscale</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
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<th>10.</th>
<th>11.</th>
<th>12.</th>
<th>13.</th>
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<tbody>
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<td>1. SS Go Reaction Time</td>
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<td>2. SS Stop Rate</td>
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<td>3. SS Commission Error Rate</td>
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<td>6. NB False Alarm Rate</td>
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<td>.05</td>
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<td>-.18^</td>
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<td>-.05</td>
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<td>.87^</td>
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<td>10. EDFLIX Total</td>
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<td>.02</td>
<td>.02</td>
<td>.22^</td>
<td>.14^</td>
<td>-.18^</td>
<td>-.04</td>
<td>-.17*</td>
<td>-.13*</td>
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<td>11. EDFLIX General Flexibility</td>
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<td>.08</td>
<td>-.09</td>
<td>.01</td>
<td>-.05</td>
<td>-.03</td>
<td>.83^</td>
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<td>12. EDFLIX Food/ Exercise Flexibility</td>
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<td>.05</td>
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<td>-.15^</td>
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<td>13. EDFLIX Weight/ Shape Flexibility</td>
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<td>.07</td>
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<td>.08</td>
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<td>-.02</td>
<td>-.09</td>
<td>-.06</td>
<td>.71^</td>
<td>.39^</td>
<td>.30^</td>
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</tr>
</tbody>
</table>

Note. SS = Stop-signal task; NB = N-back task; WCST = Wisconsin Card Sorting Task; EDFLIX = Eating Disorder Flexibility Index.

*p < .05. ^p < .001.
Table 5

Summary Table of Significant Correlations Among Emotion-Related Measures and Executive Functioning Task Indices

<table>
<thead>
<tr>
<th>Measure/ Subscale</th>
<th>NB Total Accuracy Rate</th>
<th>NB Hit Accuracy Rate</th>
<th>NB False Alarm Rate</th>
<th>WCST Total Error Rate</th>
<th>WCST Perseverative Error Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refocusing</td>
<td>-.16</td>
<td>NS</td>
<td>.14</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Other-blame</td>
<td>-.18</td>
<td>-.13</td>
<td>.12</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DERS Total</td>
<td>-.12</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Impulse</td>
<td>-.22^</td>
<td>-.13</td>
<td>.21^</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Strategies</td>
<td>-.13</td>
<td>NS</td>
<td>.12</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Depression</td>
<td>-.16</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Anxiety</td>
<td>-.20^</td>
<td>-.15</td>
<td>.13</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Note. NS = not significant. NB = N-back task. WCST = Wisconsin Card Sorting Task. All correlations presented are significant at the $p < .05$ level.

^$p < .001.$
### Table 6

*Differences in Emotion Regulation, Dysregulation, and Emotional States Among Groups*

<table>
<thead>
<tr>
<th>Measure/Subscale</th>
<th>Taekwondo Athletes M</th>
<th>Other Athletes M</th>
<th>Non-athletes M</th>
<th>df</th>
<th>F ratio</th>
<th>p</th>
<th>η_p^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-blame</td>
<td>10.9</td>
<td>10.4</td>
<td>11.2</td>
<td>2,315</td>
<td>1.87</td>
<td>.156</td>
<td>.01</td>
</tr>
<tr>
<td>Acceptance</td>
<td>12.3</td>
<td>12.0</td>
<td>12.7</td>
<td>2,315</td>
<td>1.71</td>
<td>.183</td>
<td>.01</td>
</tr>
<tr>
<td>Rumination</td>
<td>12.0</td>
<td>11.3^c*</td>
<td>12.6^c*</td>
<td>2,315</td>
<td>5.71</td>
<td>.004</td>
<td>.04</td>
</tr>
<tr>
<td>Refocusing</td>
<td>9.0^a</td>
<td>10.7^a</td>
<td>10.1</td>
<td>2,315</td>
<td>5.04</td>
<td>.007</td>
<td>.03</td>
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<td>Planning</td>
<td>12.6</td>
<td>13.2</td>
<td>12.4</td>
<td>2,315</td>
<td>1.40</td>
<td>.248</td>
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<tr>
<td>Reappraisal</td>
<td>12.3</td>
<td>13.6</td>
<td>12.8</td>
<td>2,315</td>
<td>2.46</td>
<td>.087</td>
<td>.02</td>
</tr>
<tr>
<td>Perspective</td>
<td>11.9</td>
<td>12.5</td>
<td>12.9</td>
<td>2,315</td>
<td>1.56</td>
<td>.213</td>
<td>.01</td>
</tr>
<tr>
<td>Catastrophizing</td>
<td>7.4^a, b*</td>
<td>8.7^a</td>
<td>9.0^b*</td>
<td>2,315</td>
<td>6.66</td>
<td>.001</td>
<td>.04</td>
</tr>
<tr>
<td>Other-blame</td>
<td>7.5</td>
<td>8.4</td>
<td>8.3</td>
<td>2,315</td>
<td>2.11</td>
<td>.123</td>
<td>.01</td>
</tr>
<tr>
<td>DERS Total</td>
<td>90.1</td>
<td>87.8^c</td>
<td>95.5^c</td>
<td>2,315</td>
<td>3.49</td>
<td>.032</td>
<td>.02</td>
</tr>
<tr>
<td>Nonacceptance</td>
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<td>14.0</td>
<td>14.8</td>
<td>2,315</td>
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<td>.392</td>
<td>.01</td>
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<td>14.4</td>
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<td>2,315</td>
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<td>Impulse</td>
<td>12.0^b</td>
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<td>14.6^b</td>
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<td>16.1</td>
<td>2,315</td>
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<td>.201</td>
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<tr>
<td>Strategies</td>
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<td>18.3^c</td>
<td>20.7^b, c^*</td>
<td>2,315</td>
<td>5.46</td>
<td>.005</td>
<td>.03</td>
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<td>Clarity</td>
<td>12.3^b</td>
<td>11.8^c*</td>
<td>13.7^b, c^*</td>
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<td>8.01</td>
<td>&lt;.001</td>
<td>.05</td>
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<tr>
<td>Depression</td>
<td>10.6^b</td>
<td>8.9^c*</td>
<td>14.1^b, c^*</td>
<td>2,315</td>
<td>8.53</td>
<td>&lt;.001</td>
<td>.05</td>
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<tr>
<td>Anxiety</td>
<td>8.2^b*</td>
<td>9.3^c</td>
<td>13.1^b, c*</td>
<td>2,315</td>
<td>8.70</td>
<td>&lt;.001</td>
<td>.05</td>
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<td>Stress</td>
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<td>12.9</td>
<td>15.4</td>
<td>2,315</td>
<td>2.82</td>
<td>.061</td>
<td>.02</td>
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</table>

*Note. DERS = Difficulties in Emotion Regulation Scale.*

^a^ indicates a significant difference between taekwondo and other athletes at the \( p < .05 \) level;

^b^ indicates a significant difference between taekwondo and non-athletes at the \( p < .05 \) level;

^b^* indicates a significant difference between taekwondo and non-athletes at the \( p < .001 \) level;

^c^ indicates a significant difference between other athletes and non-athletes at the \( p < .05 \) level;

^c^* indicates a significant difference between other athletes and non-athletes at the \( p < .001 \) level.
Table 7

Differences in Executive Function Task Indices and EDFLIX Scores Among Groups

<table>
<thead>
<tr>
<th>Task Index/ Measure Subscale</th>
<th>Taekwondo Athletes M</th>
<th>Other Athletes M</th>
<th>Non-athletes M</th>
<th>df</th>
<th>F ratio</th>
<th>p</th>
<th>ηp²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS Go Reaction Time</td>
<td>370.7</td>
<td>374.2</td>
<td>376.7</td>
<td>2.298</td>
<td>1.03</td>
<td>.358</td>
<td>.01</td>
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<tr>
<td>SS Stop Rate</td>
<td>15.6</td>
<td>17.5</td>
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<td>SS Commission Error Rate</td>
<td>61.0</td>
<td>60.4</td>
<td>59.1</td>
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<td>0.36</td>
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<td>.00</td>
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<tr>
<td>NB Total Accuracy Rate</td>
<td>92.8a, b*</td>
<td>84.4a*</td>
<td>84.3b*</td>
<td>2.294</td>
<td>15.90</td>
<td>&lt;.001</td>
<td>.10</td>
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<td>NB Hit Accuracy Rate</td>
<td>88.3a, b*</td>
<td>75.1a*</td>
<td>73.1b*</td>
<td>2.294</td>
<td>10.06</td>
<td>&lt;.001</td>
<td>.06</td>
</tr>
<tr>
<td>NB False Alarm Rate</td>
<td>5.2a, b*</td>
<td>10.8a*</td>
<td>10.4b*</td>
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<td>.04</td>
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<td>WCST Reaction Time</td>
<td>1401.6a, b*</td>
<td>1725.3a*</td>
<td>1749.7b*</td>
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<td>16.43</td>
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<td>.10</td>
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<td>WCST Total Error Rate</td>
<td>17.2a, b*</td>
<td>25.3a*</td>
<td>25.8b*</td>
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<td>15.11</td>
<td>&lt;.001</td>
<td>.09</td>
</tr>
<tr>
<td>WCST Perseverative Error Rate</td>
<td>12.1a, b*</td>
<td>17.0a*</td>
<td>16.3b*</td>
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<td>12.89</td>
<td>&lt;.001</td>
<td>.08</td>
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<tr>
<td>EDFLIX Total</td>
<td>153.2a, b</td>
<td>143.6a</td>
<td>143.5b</td>
<td>2.313</td>
<td>5.52</td>
<td>.004</td>
<td>.03</td>
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<td>66.4</td>
<td>65.0</td>
<td>2.313</td>
<td>1.36</td>
<td>.258</td>
<td>.01</td>
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<tr>
<td>Food/ Exercise Flexibility</td>
<td>56.7a, b</td>
<td>49.6a, c</td>
<td>52.8b, c</td>
<td>2.313</td>
<td>15.01</td>
<td>&lt;.001</td>
<td>.09</td>
</tr>
<tr>
<td>Weight/ Shape Flexibility</td>
<td>28.7b</td>
<td>27.5</td>
<td>25.7b</td>
<td>2.313</td>
<td>4.01</td>
<td>.019</td>
<td>.03</td>
</tr>
</tbody>
</table>

Note. SS = Stop-signal task; NB = N-back task; WCST = Wisconsin Card Sorting Task; EDFLIX = Eating Disorder Flexibility Index.

a indicates a significant difference between taekwondo and other athletes at the p < .05 level;

a* indicates a significant difference between taekwondo and other athletes at the p < .001 level;

b indicates a significant difference between taekwondo and non-athletes at the p < .05 level;

b* indicates a significant difference between taekwondo and non-athletes at the p < .001 level;

c indicates a significant difference between other athletes and non-athletes at the p < .05 level;
Table 8

Correlations Among Taekwondo Training Indices and Between Training Indices and Emotion Regulation, Dysregulation, Emotional States, and Executive Functioning

<table>
<thead>
<tr>
<th>Variable</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
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</tr>
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</tr>
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<td>3. Current Weekly Hours</td>
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</tr>
<tr>
<td>4. Current Weekly Days</td>
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<td>.63^</td>
<td>.86^</td>
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</tr>
<tr>
<td>5. Years of Training</td>
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<td>.25</td>
<td>.12</td>
<td>.22</td>
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<td></td>
</tr>
<tr>
<td>6. Belt Rank</td>
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<td>.34*</td>
<td>.17</td>
<td>.23</td>
<td>.88^</td>
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</tr>
<tr>
<td>Self-blame</td>
<td>-.14</td>
<td>-.21</td>
<td>-.11</td>
<td>-.11</td>
<td>-.09</td>
<td>-.16</td>
</tr>
<tr>
<td>Acceptance</td>
<td>-.19</td>
<td>-.29*</td>
<td>-.20</td>
<td>-.19</td>
<td>-.15</td>
<td>-.16</td>
</tr>
<tr>
<td>Rumination</td>
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<td>-.11</td>
<td>-.10</td>
<td>-.17</td>
<td>-.12</td>
<td>-.11</td>
</tr>
<tr>
<td>Refocusing</td>
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<td>.02</td>
<td>.24</td>
<td>.14</td>
<td>-.21</td>
<td>-.20</td>
</tr>
<tr>
<td>Planning</td>
<td>.15</td>
<td>-.03</td>
<td>.07</td>
<td>.13</td>
<td>-.10</td>
<td>-.08</td>
</tr>
<tr>
<td>Reappraisal</td>
<td>.16</td>
<td>.10</td>
<td>.22</td>
<td>.19</td>
<td>-.15</td>
<td>-.10</td>
</tr>
<tr>
<td>Perspective</td>
<td>.18</td>
<td>.14</td>
<td>.18</td>
<td>.16</td>
<td>.03</td>
<td>-.02</td>
</tr>
<tr>
<td>Catastrophizing</td>
<td>-.17</td>
<td>-.41^</td>
<td>-.25*</td>
<td>-.33*</td>
<td>-.23</td>
<td>-.25*</td>
</tr>
<tr>
<td>Other-blame</td>
<td>.09</td>
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*Note.* DERS = Difficulties in Emotion Regulation Scale; EDFLIX = Eating Disorder Flexibility Index; SS = Stop-signal task; NB = N-back task; WCST = Wisconsin Card Sorting Task.

*p < .05. ^p < .001.

109