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EXPLORING THE POTENTIAL RELATIONSHIP BETWEEN MINDFULNESS AND RATINGS OF PERCEIVED EXERTION

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ABSTRACT

EXPLORING THE POTENTIAL RELATIONSHIP BETWEEN MINDFULNESS AND RATINGS OF PERCEIVED EXERTION

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July 29, 2013

This study focuses on an evolving, interdisciplinary area of research involving Exercise Science and Clinical Psychology. It investigated the relationship between the perception of present-moment exertion or effort during exercise and a concept called mindfulness. Exertion is commonly measured more objectively using physiological measures (e.g., heart rate) or more subjectively using self-rated Ratings of Perceived Exertion (RPE). Mindfulness is characterized as "present-moment, non-judgmental awareness," or "living in the present."

Despite the acknowledged benefits of physical activity, many people find it burdensome, stressful, and emotionally taxing, especially when first starting an exercise program. Based upon previous research, it was hypothesized that mindfulness would affect RPE during exercise, and that people who by nature are "mindful" would perceive exercise-based exertion more accurately, measured by correlating an objective index of physical exertion (heart rate) and RPE. If true, mindfulness training could: 1) reduce the perception of exercise as burdensome; 2) increase motivation to exercise, and; 3) promote safety during exercise by preventing over-exertion.

Ninety undergraduate and graduate students ages18-23 were recruited from psychology courses for this study. All were fluent in English, physically healthy, and exercised three or more times per week. They completed a series of self-report paper-and-pencil questionnaires measuring mindfulness and related psychological factors. Next, they exercised on a treadmill for between 10 and 20 minutes, during which RPE were periodically assessed. Exercise intensity was gradually increased up to a predetermined heart rate level (76% of their age-predicted maximum heart rate) by varying treadmill speed and elevation. Behaviorally, this involved a transition from walking to jogging or running.

Results of this study suggested that mindfulness was significantly negatively correlated with RPE, particularly during light exercise intensity. No relationship was found between mindfulness and RPE accuracy. Overall, these results suggest that the relationship between mindfulness and RPE is likely a fruitful area for future research.

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CHAPTER 1

INTRODUCTION TO EXERCISE, PERCEIVED EXERTION, AND MINDFULNESS

Exercise has been associated with multiple health benefits, including reduced risk for certain types of cancer, cardiovascular disease, and obesity. Attaining these benefits often requires regular exercise participation as well as sustaining moderate exercise intensity, both of which are challenging for many individuals. Further, sustained moderate or high intensity exercise commonly elicits potentially uncomfortable sensations. For example, increased heart rate (HR), breathing rate, and the sensation of "burning" muscles are frequently experienced and may be appraised as unpleasant. This appraisal may lead to *under-exertion* in that effort or energy may be under-utilized or exercise may be terminated prematurely, resulting in fewer derived health benefits. In contrast, exercisers may believe they must "push through" uncomfortable sensations until pain is sensed (i.e., "no pain, no gain") to attain the benefits of exercise, a phenomenon known as *over-exertion*. For instance, "sharp, needle-like" Achilles pain (which should be appraised as harmful) may be inaccurately appraised as normal by a novice jogger, leading to over-exertion and possible injury. Over-exertion may also occur accidently by inadvertently misinterpreting sensations indicative of potential harm. Under- and over-exertion are likely due to flagging awareness of present-moment experience.

Accurately perceiving and appraising present-moment exertion and associated sensations during exercise may limit under- and over-exertion. Previous research has used the concept of *perceived exertion* (PE) (i.e., self-reported subjective appraisal of present-moment effort or strain during physical activity [Borg, 1998, p. 8]) to measure perceived present-moment experience during exercise. Yet, accurately perceiving exertion during exercise can be challenging even for physically fit individuals due to the complex variety of physiological and psychological processes occurring, such as fluctuations in HR, breathing rate, and shifts in attentional focus. Moreover, habitually sedentary individuals find this process particularly difficult, as they are often unfamiliar with physical activity and corresponding sensations and therefore need a framework within which to perceive and assess inner states. Designing such a framework is particularly urgent with increasing numbers of Americans reporting no leisure-time physical activity in the past month (over 25% in 2008; Centers for Disease Control [CDC], 2008).

Numerous studies have explored factors influencing the perceived present-moment exertion during exercise, including personality, gender orientation, HR, breathing rate, etc. To date, however, no framework has clearly explained how present-moment awareness may impact the accuracy of individuals' ratings of their PE (RPE) during exercise. Thus, mindfulness—non-judgmental, present-moment awareness (Kabat-Zinn, 1990, p. 2)—may contribute to a new method for framing the subjective experience of present-moment exercise and related RPE research. The primary focus of this review is on integrating the concepts of PE, which is typically researched in exercise science, and *mindfulness*, a concept receiving increasing attention in psychology, in the context of exercise. The overall purpose of this dissertation is to: 1) review, analyze, and critique PE research to date; 2) provide an overview of mindfulness—present-moment, nonjudgmental awareness-- and analysis of the extant literature; 3) describe a mindfulness-focused explanatory conceptualization of RPE, and; 4) describe and report findings from the current dissertation designed determine if the proposed conceptualization of PE offers a beneficial future direction.

Perceived Exertion Overview

Perceived exertion has a long history in exercise research. It is positively correlated with many concepts, particularly exercise intensity and fatigue. While exercise intensity is generally measured in objective physiological (HR, volume of oxygen consumed [VO_2]) or physical (work, torque, velocity) terms, PE is a complementary measure of exercise intensity related to subjective experience (Rejeski, 1985). Although fatigue and PE often both increase during exercise, it is possible for PE to increase without concurrent elevations in fatigue.

PE is a gestalt phenomenon, meaning that it requires integrating information from multiple sources, including various physiological, psychological, and social-environmental factors (Hutchinson & Tenenbaum, 2006). Perceived sensations from muscles, the cardiopulmonary system, joints, and other physiological systems primarily influence PE, accounting for an estimated 67% of changes in PE during physical activity (Morgan & Pollock, 1977). In addition, psychological (personality, motivation, attention) and social/environmental phenomena (presence of observers) are thought to mediate the relationship between physiological sensations and PE, accounting for the remainder of changes in PE (Morgan & Pollock, 1977).

Although psychological phenomena *should* play a fundamental role in PE research (Borg, 1998, p. 3), only 9% of PE studies from 1957-1993 explored "psychological factors" (Noble and Robertson, 1996, p. 10), illustrating a significant historical void in PE research. In more current PE literature, however, psychological phenomena, have received increased attention. Concepts of *self-efficacy* (SE; one's *perceived* ability to complete a given task; Bandura, 1997), cognitions, emotions, personality, motivation, gender-role orientation, and attentional focus are examples of phenomena shown to influence PE (for review see Salmon, Hanneman, & Harwood, 2010; also refer to Table 1 for detailed descriptions of several recent and seminal studies).

Resulting from 40 years of PE research, RPE is now accepted by the American College of Sports Medicine (ACSM, 2009, p. 120) as a subjective complement to more objective measures of physical exertion. RPE enables the monitoring of one's tolerance for exercise and predicts fatigue (ACSM, 2009, p. 82; Crewe, Tucker, & Noakes, 2008). Ratings of PE also offer insight into potentially perceptible information about internal "disturbances" and "somatic stress" (Borg, 1970) related to diseases or injury that may be difficult to objectively measure (Borg, 1990). However, introspective ratings, such as RPE, require somatic awareness, which comes with the possibility of error due to misinterpretation of sensations (Shusterman, 2008, p. 19). Further, although RPE research using exercise science methodologies (such as continuous monitoring of physiological processes including HR and VO_2), quantifies moment-by-moment changes, it has often lacked larger explanatory conceptual models or frameworks within which moderator and mediator variables related to the accuracy of RPEs can be modeled (Tuson

& Sinyor, 1993). Without such frameworks, dissemination and clinical application of results are limited. Therefore, a framework within which to improve RPE accuracy is needed.

Designing a framework to improve accurate detection and reporting of subjective phenomena associated with exertion has important implications for: exercise prescription (Bayles, et al., 1990; Dishman, 1994; Hays, 1999), prediction of unhealthy weight gain (Brock, et al., 2010), safety (Goss, et al., 2010), and exercise regimen adherence (Stetson, Rahn, Dubbert, Wilner, & Mercury, 1997). Recent research indicates that mindfulness-based approaches increase non-judgmental awareness of internal and external stimuli during exercise (Bernier, Thienot, Cordon, & Fournier, 2009; Gardner & Moore, 2004). This awareness may be closely linked to improving RPE accuracy, thus a mindfulness-focused framework for conceptualizing RPE is warranted. However, a viable explanatory framework integrating mindfulness and RPE has not yet been proposed. Reviewing and analyzing previous RPE research may help guide the design of a possible integration between mindfulness and RPE, which is proposed in the following section.

History of RPE Research and Development of RPE Scales

Early development.

The concept of PE was initially coined in the late 1950’s by Gunnar Borg. PE resulted from early psychophysiological studies of fatigue and working capacity using cycle ergometers (e.g., calibrated stationary bicycles; Borg & Dahlstrom, 1959, 1960). Borg and Dahlstrom (1959, 1960) identified significant discrepancies between subjective and objective measures of physical exertion as exercise intensity increased. A common finding was that participants reported *significant* decreases in their ability to continue exercising when, according to objective measures, physical exertion had only slightly decreased (Borg & Dahlstrom, 1959).

Borg conceptualized these discrepancies as primarily resulting from perceptual “distortions” during exercise-related stress (e.g., he proposed potentially unpleasant physiological sensations, such as increased HR, VO_2, lactic acid build up in muscles, may diminish one’s ability to accurately rate exertion (Borg, 1973). Borg (1970) postulated that changes in RPEs occurred similarly during exercise to that of other sensory modalities during studies of perception because RPEs make use of numerous sensory systems, including discomfort, movement, and cardiovascular systems. Using previously accepted methodologies that allowed participants to rate PE “freely” (i.e., choose any number to quantify PE) with minimal instruction, as exercise intensity increased, PE generally increased in a curvilinear pattern (Borg, 1998). For example, at high intensities, PE often increased sharply and was over-rated while at low to moderate intensities, PE often slowly increased and was under-rated, when compared to objective measures of exertion. These methods showed that PE generally increased in tandem with exercise intensity and task duration. However, there are significant reliability and validity concerns with this methodology, as noted in the following.

In terms of reliability, freely rating PE assumed that participants could provide accurate ratings without formal instruction or a conceptual framework within which to work. This likely resulted in: 1) inaccurate RPEs; 2) limited ability to compare RPE from session to session, and; 3) limited ability to compare across individuals, who may experience similar exertion but are unaware of how to rate them using similar increments. In terms of validity, with inaccurate RPEs, few factors influencing RPE could be identified. Moreover, potentially in part because of these limited methodologies, Borg primarily relied on observable physiological factors for his early research.

Borg (1970) suggested RPEs were positively correlated with changes in many physiological variables, including HR and VO_2. He reported that RPEs arise unconsciously and reflexively due almost solely to incoming sensory input, without cognitive appraisal (Borg, 1985; as cited in Rejeski & Thompson, 1993, p. 17). Borg wanted standardize RPE measurement to strengthen the correlation between RPEs and objective measures of exertion, believing a scale with high validity and reliability could do so. Borg then designed a standardized RPE scale, which had not been done previously.

The Borg scales.

To provide a detectable, physiologically relevant anchor point for his scale, Borg settled on HR. Borg (1970, 1973) designed a novel 15-point interval scale (6 = *No Exertion at All*; at rest, to 20 = *Maximal Exertion*) calibrated to a typical adult male's HR range from approximately 60 beats per minute (bpm; at rest) to 200 bpm (maximum). RPEs could be multiplied by 10 to approximate present-moment HR. This scale (Borg, 1970) displays a positive correlation with HR of approximately r = .7-.9 (Bar-Or, 1977). This scale is also linearly correlated with exercise intensity, in part due to the adjectives linked to odd integers (e.g., 11 = *Fairly light*, 17 = *Very hard*, etc.) (Gamberale, 1985). Since its development, this scale has demonstrated high validity and reliability across exercise modalities (see Chen, Fan, & Moe, 2002 for review; Hetzler, et al., 1991) and is consistently used in current RPE research.

According to Borg (1998), despite its reportedly high validity and reliability, a significant proportion (up to 15%) of adults of mean intelligence may be unable to understand the instructions of the 15-item RPE scale. There are several possible reasons for this, including: 1) the scale’s range (i.e., 6-20), which may appear to employ arbitrary numbers without clear reference points; 2) respondents are constrained by the judgmental adjectives used to describe exertion, which have negative affective valences (e.g., *Extremely hard*), making it difficult to capture positive experience, and; 3) minimal standardized instructions of how to rate PE (roughly one paragraph; Borg, 1998, p. 47). Borg’s Category-Ratio (CR) 10-item Scale (Borg, 1982) attempted to improve the measurement of RPEs by including a more intuitive range (0 = *Nothing at All*, 11 = *Absolute Maximum*). However, adjectives used in this scale still create the expectancy of increasing, *potentially* uncomfortable strain at higher intensity levels (e.g., *Extremely Strong*) Hence, additional scales have been recently developed.

Recent RPE scale.

To counter problems associated with the Borg RPE scales, Robertson et al (2003) designed an RPE scale for weight-lifting which incorporates pictorial representations of what a weight-lifter might look like at four RPEs, ranging from 0 = *Extremely Easy* to 10 = *Extremely Hard;* Omnibus Perceived Exertion Scale for Resistance Exercise (OMNI-RES). This scale is designed to differentiate between overall and anatomically specific RPEs, depending upon which muscles are “active” during weightlifting. For example, the scale’s validity was assessed by comparing overall RPE (widespread, holistic) with arms and legs RPEs after completing bicep curls and leg extensions (Robertson, et al., 2003). Recreational young adult weightlifters (resistance training ≥ twice per week) reported significantly higher “activated muscles” (arms and legs) RPEs compared to overall RPEs at the end of exercise. These results indicate the scale is valid and able to differentiate between anatomically specific and overall RPEs, which may improve the accuracy of RPEs by heightening awareness of sensations emanating from particular areas of the body.

To assess the scale's linearity, overall and activated muscles RPEs were compared with a physiological marker of exertion (lactic acid) and the amount of weight lifted. Both overall and activated muscles were significantly associated with physical exertion at various intensities, indicating the OMNI-RES and the use of pictorial representations of exertion may be beneficial for future RPE research involving weightlifting. The scale was recently modified and validated for use in cycling (i.e., "OMNI-Bike") with elementary-aged children (Barkley & Roemmich, 2008). However, the OMNI-Bike scale's validity as applied to adults is unclear and there are several potential concerns with both OMNI scales.

Three issues were identified with the OMNI scales and related validation studies. First, Robertson and colleagues (2003) neglected to compare RPEs using the OMNI-RES with the previously validated Borg scales because they deemed it "inappropriate," without explaining why. Second, the validity of the scale for individuals unfamiliar with weightlifting is unclear. Additional validation studies are needed with clinical populations (e.g., chronically ill) and individuals possessing a range of intellectual abilities. Third, validity and reliability studies across weightlifting modes are needed (e.g., squats, bench pressing, etc.). Moreover, additional modification of the pictorial representations on the OMNI-RES to match other modes of exercise, such as jogging, may be beneficial. To address these concerns, further validation studies of the OMNI-Bike among adults are needed. Overall, however, these scales illustrate that pictorial representations are helpful when differentiating overall RPEs from anatomically specific RPEs. These types of improvements have allowed the identification of numerous factors affecting RPEs, which are reviewed and critiqued in the following section.

Factors Influencing RPE

Various factors clearly influence RPEs. Early research primarily focused on physiological factors, but unexplained variance remained, a void partially filled by studies of social and psychological factors. The following section critically reviews research on RPE drawn from these three sources.

Physiological factors influencing RPE.

Several lines of RPE research have explored the relationship between physiological factors and RPE. Research concerning physiological factors either focused on: 1) objective, observable measures of exertion (e.g., HR, breathing rate, etc.); 2) subjective descriptions of physiological sensations of exertion, or; 3) the relationship between the two (i.e., objective and subjective). Research of objective measures has reported a litany of variables thought to be correlated with RPE, some of which are *potentially* detectable sensations.

A representative list of objective factors positively associated with RPE includes: blood lactate (see Pandolf 1983 for review), blood pressure (Pandolf, 1986), HR, and %VO_2 max (Hetzler, et al., 1991). Along with HR, VO_2 has been the highest correlate, with reported values as high as .92 (Eston & Williams, 1988). However, many of these studies report inconsistent and contradictory results, indicating a need for increased methodological standardization involving collection frequency and other refinements (Noble & Robertson, 1996, p. 112). Note, for example, the wide range of rating intervals in the “RPE collection frequency” column in Table 1. Further, the clinical utility of these results may be limited because many factors are likely undetectable or non-differentiable as isolated sensations, particularly at lower intensities, where they may occur in concert and are perceived as synonymous sensations. For instance, increased HR and blood pressure during exercise may be perceived as undifferentiated “chest fatigue.” Thus, exploring *perceived* sensations of exertion from various body areas and associated models of the processes modulating perception may refine the accuracy of RPEs.

Collecting RPEs specific to regions of the body that are active during exercise as well as body-wide/overall RPEs may heighten RPE accuracy and associated external validity, as described in the next section. Research on potentially perceptible physiological factors and related conceptual models is now considered, starting with “local” and “central” phenomena potentially related to RPE.

Central and local RPE factors.

Ekblom and Goldbarg (1971) first described short-term, task-specific, and potentially detectable sensations, such as isolated muscle fatigue and “burning” muscles as contributing to *local* RPE factors (e.g., localized to a particular body region; RPE-L). More long-term, exertion-related sensations from respiration and circulation experienced across many exercise tasks were described as *central* RPE factors (RPE-C), such as sensations of breathlessness or “heaviness” in the chest, as well as one’s “heart pounding.” Both local and central factors are: 1) generally positively associated with overall RPEs (RPE-O; Ueda, Kurokawa, Kikkawa, & Choi, 1993); 2) highly correlated with objective measures of exertion, and; 3) increase linearly with exercise intensity and/or duration. For example, as previously mentioned, a significant correlation between

RPE-L’s and blood lactate during weightlifting may be high (Robertson, et al., 2003). The buildup of blood lactate is likely undetectable in lower amounts, but its effects eventually becomes perceptible as a “burning” sensation leading to increased RPE-L’s. Illuminating sensations associated with RPE-L’s and RPE-C’s and their contribution to RPE-O’s has been the focus of previous research, such as that of Weiser, Kinsman, and Stamper (1973).

Weiser et al (1973) employed subjective reports of sensations after cycling to volitional fatigue to establish a relationship between perceived sensations and physiological fatigue (a construct closely related to PE). These researchers proposed a two-factor model of fatigue (local and central) to identify subjective sensations that were positively correlated: 1) leg fatigue (local); 2) cardiopulmonary symptoms (central); 3) general fatigue (overall); and 4) task aversion (a psychological factor due to discomfort). Reported leg and general fatigue were the most significantly correlated at r = .82, indicating RPE-L’s *may* best predict RPE-Os.

Weiser et al’s (1973) was novel for: 1) integrating physiological and psychological factors as well as local and central factors, and; 2) emphasizing *subjective* appraisal of physiological sensations of fatigue. However, there were several major short-comings, including: 1) neglecting the role of exercise intensity; 2) assuming pre-existing psychological factors do not influence RPE (e.g., inter-individual variability in sensitivity of fatigue symptoms); 3) omitting the influence of social factors; 4) concluding variability in RPE emanates almost entirely from physiological factors, and; 5) failing to account for processes potentially influencing the intensity of perceived sensations, an important implicit factor in the model that was subsequently integrated into a revised version of the model by Robertson, Gillespie, Hiatt, and Rose (1977).

Robertson et al's (1977) model included a "cognitive perceptual filter" component to explain how psychological factors (including perception) influence the perception of exercise prior to experiencing present-moment sensations. However, this version confined psychological factors to this single category without elaborating on specific factors which may influence perception of exercise. This left the *relative* contribution of local, central, and psychological factors to overall fatigue as an ambiguous contributor.

The relative contribution of RPE-L's and RPE-C's to RPE-O's likely depends upon exercise intensity, task duration, (Kinsman and Weiser, 1976; Pandolf, 1983; Robertson, 1982), and conscious perception (Mihevic, 1981; Robertson, et al., 1977). Across intensities, RPE-L's are thought to "dominate" RPE-C's if isolated sensations are sufficiently intense (Robertson, 1982). RPE-L's appear to be particularly salient within the first 30-180 seconds of exercise, at which point broader cardiovascular systems become activated and "amplify" perceived sensations. For example, Cafarelli and Noble (1976) suggested respiration may become more salient as exercise intensity increases, noting that at lower intensities (54% VO_2max) ventilation increases but RPEs do not vary significantly. However, at higher intensities (71% VO_2max) both ventilation and RPEs increased.

These findings are consistent with Robertson's review (1982), which concluded that the salience of respiratory sensations increases with exercise intensity. At lower intensities, however, awareness of kinesthetic (movement-based) and local factors may be more prominent as RPE data sources (Robertson, 1982). Yet, due to low physical demands at these intensities, exercisers may neglect these sensations, and instead focus attention on non-exercise phenomena. This runs contrary to Ueda et al's (1993) view that RPE-C's are largest contributors to RPE-O's during low exercise intensity (20-45% $VO2_{max}$) in women during swimming. However, this finding has not been replicated in other exercise modes. Overall, conscious awareness of sensations related to exertion across intensities is apparently a major contributor to PE ratings.

In summary, RPE-L's and RPE-C's are influenced by both non-perceptible and perceptible physiological factors that form the basis for these ratings and vary with exercise intensity. Psychological factors have been integrated into physiology-based explanatory models to account for otherwise unexplained variance, though these models were overly-simplistic. Actually, a range of psychological factors mediate exertion ratings and associated accuracy, as other studies have found; these are reviewed in the following section.

Psychological factors influencing RPE.

A variety of psychological and situational/social factors appear to influence RPEs, especially at low to moderate exercise intensity, where physiological sensations appear to be less salient (Boutcher & Trenske, 1990; Hall, Ekkekakis, & Petruzzello, 2005). The following section reviews key psychological factors that are increasingly explored in RPE research, including: 1) social factors; 2) emotions (affect, anxiety and depression); 3) SE, and; 4) stress reactivity, based on Lazarus & Folkman's (1984) Transactional Model of Stress. Table 2 summarizes psychological factors and RPE research.

Social factors may impact RPE.

Present-moment (i.e., contextual) social factors may influence RPEs, possibly as part of a larger RPE gestalt. Based on a literature review, Rejeski (1981) noticed that RPEs often fluctuate between both within- and between-individuals across exercise sessions. For example, person A’s highest RPE may be consistently higher than person B’s (i.e., between-individual variance). For each individual, RPEs may also fluctuate from one exercise session to the next (i.e., within-individual variance). He proposed an explanatory model integrating present-moment contextual factors, such as social phenomena, to explain this variance.

Rejeski (1981) conceptualized RPE by integrating biological/physiological, psychological, and social factors. He labeled RPE as “a social psychophysiological” integration and designed a model similar to Engel’s (1977) “Biopsychosocial Model” of health and disease, which highlighted the importance of psychological and social factors for health. He suggested that present-moment psychological (emotion, motivation, personality, etc.) and social (perceived feedback from observers) factors somehow integrated with physiological sensations to determine RPEs. This model advanced RPE research by incorporating present-moment contextual factors and illuminated the need for broader conceptual models. However, this model is limited in its failure to account for individual differences in exercise awareness of present-moment contextual factors, which could lead to under- or over-exertion.

Subsequent research indicated performing exercise alone or with others present can influence RPEs (Hardy, Hall, & Prestholdt, 1986). Hardy et al (1986) reported RPEs were significantly lower during a cycle ergometer task at low (25% VO_2max) and moderate (50% VO_2max) intensities among undergraduates with an observer present.

However, the influence of social factors became non-significant at high exercise intensity (75% VO_2max), indicating social factors may be primarily influential at low and moderate intensities (see Hardy, et al. [1986] in "Social Influence" section of Table 1 for detailed description of study). The external validity of these results is limited due to the small sample size (*n* = 9) and individualized exercise sessions, uncommon in many activity settings. The latter issue was addressed in a related study.

In a second study, Hardy et al (1986) explored the influence of a co-actor (a confederate exercising simultaneously) on RPEs. Participants completed a cycle ergometer task at 50% VO_2max with a co-actor cycling at low (25% VO_2max) or high intensity (75% VO_2max). RPEs were significantly lower when the co-actor rode at low intensity, suggesting awareness of co-actor's exertion influences RPEs. However, in both studies, the authors did not address how specific observer/co-actor characteristics (e.g., awareness, sex, attractiveness, etc.) affected RPEs.

In general, awareness of others appears to influence RPEs, but research in this area is at an embryonic stage. It reveals a void in RPE research, and points to a need for additional studies on social and other psychological factors occurring during exercise. We turn now to emotions, another potential contributor.

Emotions may impact RPE.

Research suggests a relationship between emotions and RPEs, particularly general affect as well as anxiety and depression. A link between these concepts is proposed due to their relationship with broader emotion experiences.

Positive and negative affect may influence RPE.

Let us first consider the relationship between affect--defined as all valenced responses that are basic and irreducible, often not directly tied with a particular stimulus (pleasure-displeasure)--and RPE during exercise. Affect and RPE are related across exercise intensities. Hardy and Rejeski (1989) suggested if RPEs represent “what” one feels during exercise, affect represents “how” one feels, which could have important implications for the accuracy of RPEs.

Recent research uses exercise-specific, real-time, likert-type measures to model affect (positive-negative) and arousal (low-high). Presumably, like RPE, affect states, may vary during the course of an exercise session, and thus should be addressed frequently. These methodologies foster an increased understanding of affect *during* exercise. For instance, contemporary methodologies suggest both positive (PA) and negative affect (NA) are often experienced during exercise and significantly correlated with RPEs. At low to moderate intensities, PA is typically highest (Ekkekakis, Hall, & Petruzzello, 2004; notice correlations in “Outcome(s)” column become increasingly negative between RPE and affect [measured by the FS] as exercise intensity increases in Hardy & Rejeski Exp. #3 in “Affect” section of Table 1). Ekkekakis and colleagues (2000) reported that during a 15 minute self-paced walk, perceived arousal and PA increased progressively from pre- to post-task. In contrast, NA follows a different trajectory.

During high intensity exercise, NA often progressively increases as RPE increases (notice increasingly negative correlations between RPE and FS in “Outcome(s)” of Acevedo, Gill, Goldfarb, & Boyer, 1996; Hardy & Rejeski, 1989 in “Affect” section of Table 1). Ekkekakis (2003) conceptualized increased NA as due to the transition from aerobic metabolism, when energy resources are substantial, to anaerobic metabolism, which limits energy resources, and may be perceived as more stressful. At these intensities, the influence of psychological constructs on affective valence, are thought to decrease (Ekkekakis, et al., 2004).

A past review of affect and exercise suggested affective valences change rapidly during exercise, but the mechanisms driving the change and how affect influences RPE accuracy remain unclear (Reed, 2005). The most valid data collection frequency to maintain natural exercise experience is unclear, with frequencies varying widely in past research from one minute (Hardy & Rejeski, 1989) to 30 minute intervals (Acevedo, Gill, Goldfarb, & Boyeer, 1996), which vastly limits understanding and predicting trends in RPE and affect. Generally, PA is discussed as partially the result of increased physiological activation, which is healthy and adaptive from an evolutionary perspective to increase exercise enjoyment and possibly exercise participation (Heinreich, 2001 p. 164). However, this research is anecdotal in nature. Negative affect may also be adaptive by serving as an indicator to guide one's attention towards a risk for potential injury or flagging energy, such as during high intensity exercise (Ekkekakis, 2003). However, it is unclear how fluctuations in affect may influence the accuracy of RPEs. For instance, experiencing intense PA or NA may act as distracters from present-moment tasks and decrease one's ability to notice cues requiring attention, such as changes in breathing rate or dehydration.

In conclusion, it is apparent that affect and RPEs are related. Recent affect assessment measures have collected real-time data using bipolar likert measures to explore how affect changes during exercise. I now consider the impact of negative emotions--anxiety or depression--on RPEs.

Symptoms of anxiety and depression may influence RPE.

Early, seminal studies (Morgan, 1969, 1968, 1973; Morgan, Hirta, Weitz, & Balke 1976; Morgan, Raven, Drinkwater, & Horvath 1973) suggested anxiety and depression symptoms decrease perceptual accuracy, in relation to objective measures of exercise intensity (see “Psychopathology” section in Table 1 for detailed description of Morgan, 1969, 1973). In a review of his own work, Morgan (1994) reported eight out of 75 ratings (11%) of perceived exercise intensity using a cycle ergometer in adult males illustrated significant perceptual errors at submaximal intensities. All but one of the errors occurred among participants scoring 1.5-2.0 *SD* from norms on self-report measures of anxiety, neuroticism, or depression (see “Outcome[s] column in Morgan [1973] for detailed description in “Psychopathology” section, Table 1).

Perceptual errors in perceived exercise intensity likely indicate poor awareness of changes in physical exertion required at different exercise intensities, suggesting a decreased likelihood of accurate RPEs. However, these studies used paper-and-pencil-based measures of anxiety designed for non-exercise contexts. Confusion related to overlapping items also tapping somatic sensations due to exercise threatens the validity of applying psychological measures in this manner (Rejeski, Hardy, & Shaw, 1991). For example, increased HR or sweating during exercise involves physiological reactions that are similar to physical symptoms of anxiety. Moreover, validity concerns are evident as early RPE studies exploring anxiety and depression had small sample sizes (as few as nine participants [Morgan, 1973]).

Limited subsequent recent research has explored the influence of anxiety on RPEs, with findings conflicting with Morgan’s (1968, 69, 73) reports. Results from a treadmill task at low (20% VO_2max below ventilator threshold [VT]), moderate (at VT), and high (10% VO_2max above VT) intensity among young, presumably healthy adults reported no significant relationship between anxiety and RPE (Hall, et al., 2005). These findings should be used with caution, however. Hall et al (2005) administered the Eysneck Personality Inventory (a general measure of personality), opposed to an anxiety-specific measure that may provide more detailed data.

In conclusion, depression and anxiety symptoms *may* influence the accuracy of RPEs. However, it is likely that there are multiple influential factors that were not explored in previous research, such as severity, duration, and treatment of symptoms. There is currently a dearth of research exploring these factors. Implicit in this line of research is that individuals may vary in awareness of these sensations during exercise. Therefore, the next section focuses on somatic awareness and factors related to appraising and managing sensations of exertion during exercise.

Components of stress reactivity may influence RPE.

Acevedo and Ekkekakis (2001) hypothesized that appraisal (defined in “Appraisal” section below) mediates perceived intensity of physiological sensations associated with exertion in physically stressful environments, resulting in changes in affect and RPEs. Further, this model proposes that appraisals can influence how one manages (i.e., copes) with sensations related to exertion. A limitation of the Acevedo and Ekkekakis (2001) model is that awareness of exertion-related sensations may precede these processes. Thus, the following section reviews and critiques research related to an updated framework of stress processes, including: 1) somatic awareness; 2) appraisal processes, and; 3) coping strategies, with an emphasis on attentional focus.

Somatic awareness during exercise affects RPE.

Somatic awareness is an important factor in the relative accuracy of RPEs. This may include awareness of numerous physiological sensations across exercise intensities, such as proprioceptive (spatially-based), kinesthetic, nociceptive (pain-based), and interoceptive (organ-based). This awareness may increase RPEs as well as their accuracy, and is reviewed and analyzed in the following paragraphs.

Kinesthetic and proprioceptive sensations have been proposed to be particularly salient at lower intensities (Robertson, 1982), while interoceptive or nociceptive sensations have been thought to be more influential at moderate to high exercise intensities (Robertson, 1982). To explore the role of somatic awareness in RPEs during a self-paced jogging task, Pennebaker and Lightner (1980) assigned participants to either a control condition or a condition in which participants heard their own breathing or distracting environmental sounds. Participants in the breathing condition reported significantly more fatigue and physiological symptoms (e.g., racing heart, stiff or sore muscles, etc.) compared to the other conditions. These results suggest attending to interoceptive cues increases somatic awareness and fatigue, which *may* increase RPEs and decrease the risk of over-exertion. However, this study relied on self-reported symptoms to assess interoceptive awareness, which may be less valid than awareness accuracy tasks, such as heart beat detection or breathing rate estimation.

Recent research has increasingly incorporated behavior measures of interoceptive awareness. Herbert, Ulbrich, and Schandry (2007) employed a heartbeat detection task to measure interoceptive sensitivity and monitored HR to assess physical exertion. Participants with high and low interoceptive sensitivity were compared. During a self-paced cycling task, highly sensitive participants covered significantly less distance and experienced a lower increase in mean HR, suggesting high sensitivity may be related to decreased likelihood of over-exertion. Authors recommended interoceptive sensitivity training to optimize effort and energy expenditure, but specific interventions have not been examined. It remains unclear if HR detection is the most valid interoceptive sensitivity measure *during* exercise; it was the only tool employed in this study and was completed while at rest. Instead, a test of respiratory awareness (e.g., breathing rate or volume) may prove beneficial, as these sensations may be increasingly monitored as exercise intensity increases (Cafarelli & Noble 1976; Robertson 1982).

In summary, numerous somatic sensations influence RPEs, with sources of influence likely depending upon exercise intensity. At lower exercise intensity, kinesthetic and proprioceptive sensations may be more influential, while at higher intensities, interoceptive and nociceptive sensations may be more prominent (Robertson, 1982). Potentially across intensities, when exercise intensity is self-titrated, awareness of sensations likely results in less frequent under- or over-exertion, eliciting more accurate RPEs. Accurate RPEs require appraisal of perceived exertion-related sensations, as examined in the following section.

Appraising sensations related to exertion impacts RPE.

In the context of exercise, appraisals occur regularly due to the constant flow of information from psychological, physiological, and environmental sources (Acevedo & Ekkekakis, 2001). Lazarus and Folkman (1984) define appraisal as "…a recurring evaluative process of environmental stimuli to determine if a situation is stressful" (p. 19). Accurate appraisals of this information are crucial to maintaining safety.

Appraisals can distort perceived sensations by intensifying or minimizing their intensity and thereby reducing the accuracy of RPEs, presenting a marked safety risk, such as under-exertion (Acevedo & Ekkekakis, 2001; Ekkekakis, et al., 2004). For example, cardiac rehabilitation patients experiencing increased heart and breathing rates (within normal, recommended ranges) during exercise may inaccurately interpret these physiological responses as negative and indicative of a myocardial infarction, leading to unnecessary exercise session termination and decreased exercise-related health benefits. Accurate appraisals may be facilitated by heightened awareness of present-moment sensations. However, there is currently no available research focusing on present-moment appraisals of sensations and RPEs.

In summary, appraisal processes likely significantly influence RPE accuracy. Accurate appraisals may be facilitated by present-moment awareness of sensations, resulting in more accurate exercise titration and RPEs to prevent under- or over-exertion. Appraisals likely affect strategies to manage sensations related to exertion, which are reviewed in the following section.

Coping strategies influence RPE accuracy.

Recent research indicates high intensity exercise often requires mental or physical coping--"constantly changing cognitive and behavioral efforts to manage...demands that are appraised as taxing or exceeding the resources of the person" (Lazarus & Folkman, p. 141)--to manage associated demands as exertion increases (Acevedo & Ekkekakis, 2001). Physiological responses to high intensity exercise are similar to those experienced by various events typically labeled as “stressful” (Howley, 1976), including trauma or physiological pain (Selye, 1950). During both high intensity exercise, the sympathetic nervous system becomes activated in reaction to situational stressors, including the release of Catecholamines (Howley, 1976).

Strategies to cope with this stress can include biomechanical or mental adjustments (e.g., attentional focus). Attentional focus may lead to more accurate RPEs and adaptive biomechanical adjustments, such as adaptive changes in pace, stride length, etc., to prevent over-exertion. Hence, attentional focus is the concentration of the following section.

Attentional focus as a coping strategy influence RPE accuracy.

Attentional focus is an important factor of RPEs during exercise. Attentional focus is often viewed as a strategy to modulate the perceived intensity of sensations. Morgan and Pollock (1977) dichotomized attention as “associative” (A) or “dissociative,” (D) a view that was dominant for several decades. Nideffer (1976) also proposed a complex model graphing attentional focus along *both* “broad-narrow” and “internal (toward present-moment stimuli)- external (environmental stimuli).” Within this model, flexibly shifting attentional focus may display the fluidity of cognitive strategies during exercise and facilitate active, responsive strategies.

Associative strategies are those in which the focus of attention is on internal stimuli (psychological or physiological) directly related to the experience of exercise. In contrast, dissociative strategies involve focusing attention away from internal experience. Associative states are often employed by elite athletes (Morgan & Pollock, 1977) to “fine-tune” biomechanics and identify physiological changes requiring intentional modification through present-moment focus. For example, awareness of fatigue in a runner's arches could necessitate changing stride length, or cadence. Association has been linked with higher RPEs, potentially indicating an inaccurate amplification of perceived intensity of sensations.

On the other hand, use of dissociative strategies likely decrease perceptual clarity by neglecting potentially salient physiological input (Morgan & Pollock, 1977). Examples of such strategies include listening to music or mental arithmetic. Implicit in dissociation is that present-moment experience is unpleasant and to be avoided. Rigid employment of such strategies could increase risk of injury, particularly during high intensity exercise where inattention to relevant cues (i.e., pain, fatigue, dehydration, etc.) may be risky. Also, these strategies may diminish the perceived intensity of sensations (Salmon, et al., 2010) and result in lower, less accurate RPEs. This is likely due to ignoring sensations as they arise. However, until recently, the role of exercise intensity received little attention.

A recent conceptualization of RPE integrated exercise intensity and attentional focus (Hutchinson & Tenenbaum, 2007; Tenenbaum 2001). Tenenbaum (2001) suggested as exercise intensity increases, attention progressively shifts towards association to monitor physiological stress. Additionally, as RPEs increase, the salience of psychological factors diminishes. This model, however, 1) fails to review how various processes affect perception and the perceived intensity of sensations, and; 2) bifurcates attention along an A-D continuum, which fails to account for the dynamic, fluid nature of attentional focus during exercise (Salmon, et al., 2010).

Attentional focus has become increasingly important in RPE research. A significant amount of RPE research dichotomized attentional focus as either associative or dissociative. Subsequent research (Salmon, et al. 2010) has shifted towards a proposal similar to Nideffer's (1976), in which attention flexibly shifts, based on present-moment requirements. However, published models of attention and RPE remain somewhat limited and do not illustrate the experience of flexible attentional focus and its relationship with the accuracy of RPEs.

In summary, somatic awareness, cognitive appraisals, and coping strategies may influence RPE accuracy. Present-moment focus appears to affect identifying, appraising, and coping with sensations related to exertion; however, there is currently no framework linking these factors to RPE accuracy. Yet, recent RPE research has suggested the concept of SE may affect RPE accuracy.

Self-Efficacy may influence RPE.

Self-efficacy (SE; Bandura, 1997) and somatic awareness may both be related to awareness of present-moment abilities relative to task demands. A growing body of literature suggests a relationship between SE and RPE. Higher SE is presumed to result in increased perceived ability to address present-moment challenges, such as exercise. However, the strength and direction of the relationship between SE and RPEs is unclear.

Several studies have reported a negative relationship between pre-exercise SE and RPE. McAuley and Courneya (1992) found that pre-exercise SE is negatively correlated with RPEs in sedentary middle-aged adults completing a cycle ergometer task at moderate exercise intensity (70% predicted MHR; see McAuley & Courneya [1992] in "SE" section of Table 1 for detailed study description). Using a cycle ergometer task at moderate intensity (60% VO_2peak), Pender, Bar-Or, Wilk, and Mitchell (2002) also reported a negative correlation between pre-exercise SE and RPEs in elementary and middle-school age girls (see Pender, et al. [2002] in "SE" section of Table 1 for detailed study description). To explore whether this relationship depended on exercise intensity, Hall et al (2005) found that SE and RPE were significantly negatively correlated at lower and moderate but not high intensities in young, presumably healthy adults (see in Hall, et al. [2005] in "SE" section of Table 1 for detailed study description). However, in these studies, RPEs were averaged across the task, which may decrease the validity. Monitoring changes in RPEs across intensities may identify when RPEs are most accurate, which is possible with advanced statistical methodologies, such as latent growth curve modeling.

Using latent growth curve modeling (a statistical technique capable of graphing specific changes over time), recent studies suggest exercise SE may be positively related to more accurate RPEs. Hu, McAuley, Motl, & Konopack (2007) demonstrated higher SE is associated with more gradual (and possibly accurate) increases in RPEs in older sedentary adults during a treadmill-based protocol in which exercise intensity increased up to VO_2 max (see Hu, et al. [2007] in "SE" section of Table 1 for detailed description). The implication of this study is that increasing SE may increase RPE accuracy. Thus, Hutchinson, Sherman, Martinovic, and Tenenbaum (2008) explored the malleability of exercise-specific SE.

Hutchinson et al (2008) proposed that experimenter feedback could be used to manipulate SE to influence subsequent RPEs during a handgrip task. Participants were randomly assigned to one of three conditions (low SE, High SE, control) to receive bogus performance feedback (e.g., “your performance falls in the Nth percentile”), with the high SE condition receiving the most positive feedback. Participants in the high SE condition reported significantly lower RPEs during subsequent trials, compared to the other conditions (see Hutchinson, et al. [2008] in “SE” section of Table 1 for detailed study description). These results suggest SE may be modified as a function of present-moment feedback, resulting in lower RPEs. However, the external validity of these results to other exercise modes is unknown.

In summary, available research suggests SE is likely either negatively associated with RPE or associated with more gradual increases in RPEs, which may indicate greater RPE accuracy. There are several explanations for the variability in this relationship, including inconsistencies among this research involving: 1) RPE collection frequency (see “RPE Collection Frequency” column in Table 1); 2) heterogeneity of sample characteristics; 3) heterogeneity of exercise mode, and; 4) varying statistical methodologies.

Summary of factors influencing RPEs and overall critique of RPE research.

Various physiological and psychological factors influence RPEs, including: 1) central and local factors; 2) social awareness; 3) emotions; 4) stress reactivity (factors related to the Transactional Model of Stress), and; 5) SE. There are several methodological concerns with available RPE research, including: 1) omission of data on RPEs as exercise intensity decreases; 2) over-reliance on Borg 15-item RPE scale; 3) inconsistent RPE collection frequency; 4) significant variability among exercise modes and participant characteristics; and 5) limited data on factors increasing RPE accuracy. However, the significant relationships among physiological and psychological factors reported in numerous studies suggest that exercisers have the capacity to increase RPE accuracy by taking these factors into account. To date, no comprehensive explanatory RPE framework has linked these elements together. To address this omission, mindfulness (introduced in the following section) is proposed as the foundation for a conceptual RPE framework that may result in more accurate RPEs.

Mindfulness

Perhaps the most widely cited working definition of mindfulness is that of Kabat-Zinn (1990), who defined it as “non-judgmental, present-moment awareness” (p. 2). However, Bishop (2002) identified a lack of an operational definition of mindfulness. An operational definition of mindfulness was suggested as: 1) self-regulation of attention towards present-moment experience, and; 2) a mental orientation characterized by “curiosity, openness, and acceptance” (Bishop, et al., 2004). Yet, continued inconsistency among definitions of mindfulness has been noted (Grossman, 2008), with research (Shapiro, Carlson, Astin, & Freedman, 2006) frequently defining it as “present-moment, non-judgmental awareness (Kabat-Zinn, 1990, p.2). Thus, mindfulness will be operationalized using Kabat-Zinn’s (1990) definition. Mindfulness practice has been formalized in various interventions, including stress reduction.

Originally developed in 1979, *mindfulness-based stress reduction* (MBSR) programs have been widely employed to help medical patients reduce stress. MBSR focuses on practicing present-moment, non-judgmental awareness through exercises designed to heighten focused awareness of one’s inner experiences as they emerge into conscious experience and to reduce the automaticity of judgment (e.g., “good,” “bad,” “right,” “wrong”). The components of MBSR and associated validation studies are discussed in-depth elsewhere (Grossman, Niemann, Schmidt, & Walach, 2004; Salmon, Santorelli, Sephton, & Kabat-Zinn, 2008). The construct of mindfulness has been examined in a burgeoning literature that is indirectly related to exercise.

An integral aspect of MBSR programs is movement, which is embodied in Hatha Yoga practice (a component of MBSR), where it is synchronized with respiration and thought to heighten awareness of sensations emanating from muscles, joints, and internal organs. Although movement is an important factor in MBSR programs (Kabat-Zinn, 1990, p. 97), research on mindfulness in the context of exercise has only recently received attention (see “Number of sessions; Themes/Components” column in Table 3 for mindfulness-based exercise programs components and detailed description of related studies).

In the context of aerobic exercise and sport, mindfulness-based performance enhancement interventions have been designed, including the *Mindfulness-Acceptance-Commitment Approach* (MAC) to human performance (Gardner & Moore, 2004) and *Mindful Sport Performance Enhancement* (MSPE; Kaufman, Glass, & Arnkoff, 2009). The MAC approach is a 12-week program focusing on strategies to increase awareness and acceptance of internal experience and external stimuli (Gardner & Moore, 2004). Similarly, MSPE is a 4-week program designed to integrate MBSR and mindfulness-based psychotherapy techniques to improve athletic performance. Techniques in MSPE include mindfulness meditation (MM), body scan (progressive mental scan of the body), walking meditation, and mindful yoga (see “Outcome[s]” column in “MSPE” section in Table 3 for description of results). There have also been non-manualized strategies published related to mindfulness-like states, such as *Zendurance* (Eversfield, 2003) and *ChiRunning* (Dreyer, 2004).

These books suggest that states apparently similar to mindfulness may: decrease (Eversfield, 2003) or eliminate unnecessary effort (Dreyer, 2004, p. 55), and improve safety via biomechanical adjustments through mind-body awareness (Dreyer, 2004, p. 20). Furthermore, there is increasing cultural interest in incorporating mindful-like states into exercise, with numerous workshops and websites dedicated to the topic (*www.chirunning.com;* ChiLiving, 2010). However, relatively few empirical studies on mindfulness exist in this area, with only four available studies on MAC and MSPE and three studies exploring the influence of mindfulness *during* exercise. Yet, these studies indicate mindfulness may be a salient construct in enhancing awareness of present-moment phenomena during exercise. Thus, the following section designs a mindfulness-focused framework for conceptualizing RPEs by reviewing constructs which influence RPEs and their relationships to mindfulness at various exercise intensities.

RPE and Mindfulness Framework

There is sufficient focus within current mindfulness research on constructs highlighted in the “Psychological factors and RPE” section of this paper to warrant a mindfulness-focused RPE framework. Currently, however, due to a lack of research on mindfulness and RPE, it was difficult to predict precisely how they are related. This framework reviews mindfulness-focused research of concepts related to RPE and is grouped *similarly* to the “Psychological factors” section, including: 1) social awareness; 2) emotions (affect, anxiety and depression); 3) factors related to stress reactivity during exercise, based on the Transactional Model of Stress, and; 4) SE.

Potential linkages between the construct of mindfulness and social awareness.

Mindfulness and social awareness may be positively associated. For example, in the context of basketball, mindful-like states have been discussed as increasing awareness of internal reactions to other individuals, such as feeling angry due to a “bad call” (Jackson & Delehanty, 1995). Thus, mindfulness is predicted to be positively associated with heightened awareness of social cues, potentially resulting in dampened reactivity to social stimuli, which could increase RPE accuracy. However, there is no available research focusing on how mindfulness may heighten sensitivity to social cues that may affect RPE accuracy. This is a noticeable void based on the salience of social factors in extant RPE research and their relationship to constructs known to be associated with RPEs, such as emotions, are discussed in the following section.

Mindfulness may influence emotions.

Mindfulness may increase positive affect and decrease negative affect.

A burgeoning body of research suggests exercise increases positive affect (PA) up to a certain intensity (usually upper moderate or high intensity) at which point negative affect (NA) increases (Ekkekakis, et al., 2004). Mindfulness is hypothesized to delay the transition from PA to NA and decrease the valence (e.g., intensity) of reported NA as exertion increases. However, self-reported affect implicitly requires judgment. From a mindfulness framework, affect is impermanent. Being immersed in or attempting to suppress affect or emotions is viewed as potentially maladaptive, leading to psychological distress (Nyklicek, 2011), and possibly inaccurate RPEs.

Emotional awareness and “experiencing” emotion non-judgmentally are encouraged in mindfulness-based interventions (Baer & Krietemeyer, 2006, p. 22), opposed to avoiding contact with emotions (i.e., *Experiential Avoidance* [Hayes, Wilson, Gifford, Follette, & Strosahl, 1996)]). During Experiential Avoidance, experiences perceived as unpleasant are avoided to reduce difficulties (Hayes, et al., 1996). Calogero and Pedrotty (2007) suggest mindfulness may help connect emotions with awareness of cognitions and physiological responses to exercise, which could improve safety by being less “distracted” by affect that could lead to over- or under-exertion. It may be possible that a mindful experience of affect includes suspension of, or decreases in, reported affective valence. However, there are currently no exercise-specific measures to assess real-time non-judgment, which makes it challenging to identify the appearance of a mindful affective experience without comparison to less mindful individuals.

Mindfulness has been associated with dampened cognitive reactions to reported sad mood states, indicating an ability to experience and tolerate NA (Raes, DeWulf, Van Heeringen, & Williams, 2009). Additionally, Waters et al (2009) reported among smokers completing a challenging mental task (modified Stroop task), mindfulness was negatively associated with NA and positively associated with PA. However, the external validity of these results may be limited to non-smokers and exercise-contexts. Additionally, data were only collected once, negating possible longitudinal analyses. This illustrates a need for real-time assessment measures of mindfulness, without which may falsely assume that data from isolated time points generalize to other potentially salient time points.

In summary, mindfulness shows promise as potentially increasing PA and assuaging NA. However, pre- post- task data collection methodologies limit the generalizability of these findings to exercise contexts. Moreover, there are currently no studies of mindfulness and real-time affect during exercise (notice *zero* studies included measures of real-time affect in “Measures” column of Table 3). Exploring the relationship between mindfulness and symptoms related to NA, such as anxiety or depression, may identify opportunities to increase RPE accuracy, as discussed in following section.

Mindfulness may decrease anxiety and depression.

Morgan (1968, 1969, 1973) reported symptoms of anxiety and depression were associated with more frequent errors in perception of exercise intensity. Unfortunately, there are currently no available studies of mindfulness and its relationship with anxiety, depression, and RPEs. However, mindfulness-based psychotherapy has been: 1) shown to significantly increase self-reported mindfulness (see Table 2 for detailed description of Lovas & Barsky, 2010; Weber, et al., 2010), and; 2) negatively associated with anxiety and depression (see Evans, et al., 2008; Foley, et al., 2010 in “Mindfulness-based Cognitive Therapy [MBCT] Section” of Table 2 for detailed description or Foley, et al., 2010; Lavas & Barsky, 2010; Weber, et al., 2010).

This line of research suggests higher mindfulness may decrease anxiety and depression symptoms, likely increasing perceptual accuracy. However, sample sizes were often were small, with four recent studies reporting *n’s* ranging from 10-15 participants (see “Participants and Sample Size” column in “ MBCT” section in Table 2), which limits external validity. Additionally, many of these studies only completed data collection in some combination of baseline, end of treatment, and one follow-up (see "Data collection frequency" column of Table 2), which fails to identify potentially salient changes occurring on a more frequent basis. Also, only two out of five studies reviewed in the "Anxiety and Depression" section of Table 2 interviewed participants to diagnose anxiety and depression, while the remaining studies relied solely on self-report questionnaires. This may limit the accuracy of diagnoses and decrease the validity of results. A combination of a clinical interview and self-report measures of depression is preferable in diagnosing these symptoms (Holtzheimer, et al., 2010).

These studies suggest mindfulness may increase perceptual accuracy of present-moment stimuli during exercise by decreasing anxiety and depression symptoms, possibly resulting in more accurate RPEs. However, it is unclear at which exercise intensities mindfulness may influence RPE accuracy.

Mindfulness may influence factors related to stress reactivity during exercise.

Mindfulness may increase somatic awareness.

Mindfulness has been described as increasing somatic awareness, a focal point in several mindfulness-focused programs (e.g., Tophoff, 2004). Bernier et al (2009) reported similar findings using the MSPE intervention with young adult swimmers, suggesting mindfulness promotes heightened awareness of bodily sensations in the context of sport and exercise. However, this study utilized qualitative data (i.e., interviews), which reduces the validity and reliability of the findings, due to potential social pressure to report heightened awareness after a time-intensive intervention.

O'Loughlin and Zuckerman (2008) reported that self-reported mindfulness (scores on the (MAAS; Brown & Ryan, 2003) among undergraduates predicted a significant negative relationship between a pre-existing steroid in the body suggested as representative of overall physical health (dehydroepiandrosterone; DHEA) and perceived health (measured by self-reported physical symptoms). Their findings suggest that mindfulness may reduce apparent discrepancies between objectively measured physiological symptoms and perceived symptoms, possibly increasing RPE accuracy. However, DHEA may be a poor marker of overall physical health, as no significant correlation was reported between DHEA and reported physical symptoms. Additionally, it is unclear how these results may generalize to chronically ill populations, for whom awareness of physical symptoms may particularly salient to prevent under- or over-exertion during exercise. Yet, somatic awareness is important in RPEs, as described by Robertson (1982).

Robertson's (1982) review of exertion during exercise proposed at high exercise intensities, breathing rate and volume are the only consciously perceived and monitored central factors of RPE. However, additional research is needed to establish the validity of this proposition, or if HR may also be consciously monitored during high exertion. Regardless, mindfulness or previous MM experience is hypothesized to bolster the accuracy of RPEs by promoting awareness of respiratory sensations, as well as not judging these sensations (Kabat-Zinn, 1990, p. 34). Significant meditation experience (> 9 years) has been positively associated with thicker neural areas linked to awareness of respiration rate compared to matched controls (Lazar, et al., 2005). Lazar et al's (2005) results may indicate mindful individuals are more aware of sensations related to respiration and associated RPE-C factors. This awareness may result in greater physiological control, allowing for biomechanical adjustments, such as postural changes

(Holland, 2004). However, no present-moment respiratory awareness task was administered to confirm heightened sensitivity, which may reduce the validity of the results.

A separate line of research suggests mindfulness may *not* improve interoceptive awareness. Khalsa, et al. (2008) found no significant differences regarding interoceptive awareness between frequent (≥ 15 years meditation experience) meditators (Kundalini yoga; Tibetan Buddhist meditation) and non-meditators on a pulse rate detection accuracy or HR detection task. However, with only 13-17 participants in each condition, this study may have attained statistically significant results with increased statistical power, such as employing a larger sample size. Additionally, heart and pulse rate detection may be a poor index of interoceptive awareness (Khalsa, et al., 2008) and current technologies may not yet be advanced enough to measure associated mental processes (Wallace, 2009, p. 24). Further, this study essentially assessed “stimulus threshold” (e.g., required stimulus intensity to perceive sensations), when it is also plausible that mindfulness does not influence *if* someone perceives a stimulus, but rather *how* sensations are experienced and appraised once perceived.

In summary, mindfulness may enhance present-moment somatic awareness, including heightened sensitivity to changes in interoceptive sensations known to influence RPEs, such as HR or breathing rate. This awareness may increase the accuracy of RPEs and help accurately titrate exercise intensity. However, this research relied on self-report mindfulness measures designed for non-exercise contexts and has not yet identified valid and reliable measures of real-time interoceptive awareness, possibly decreasing their validity.

Mindfulness may increase accurate appraisals.

Mindfulness may bolster RPE accuracy by modifying present-moment appraisals of exertion-related sensations. It is likely that mindfulness encourages positive, neutral, or non-judgmental (e.g., no judgment) appraisals, as mindfulness has been proposed to increases self-acceptance (Thompson & Waltz, 2008). In non-exercise contexts, mindfulness has been associated with more benign or positive appraisals (Garland, Gaylord, & Park, 2009; Weinstein, Brown, & Ryan, 2009), suggesting fewer negative appraisals and decreased perceived stress (Cordon, Brown, & Gibson, 2009; Lau, et al., 2006).

Non-judging is a core characteristic of mindfulness likely to influence the valence of judgments, as described by Kabat-Zinn's (1990) "attitudinal foundations of mindfulness" (p. 33). A concept called *decentering*, defined as the ability to cognitively "step outside of one's immediate experience" (Safran & Segal, 1990, p. 117) may foster non-judgment (Shapiro & Carlson, 2009, p. 95). Decentering has been linked with mindfulness (Shapiro & Carlson, 2009, p. 94) and decreased reactivity to negative or repetitive thoughts (Feldman, Greeson, & Sensville, 2010), indicating acceptance of one's performance. However, participants were limited entirely to female undergraduates. Use of retrospective self-reports also limits validity.

MAC and MSPE approaches draw from MBSR and mindfulness-based psychotherapy to encourage exercisers to identify and accept a wide range of non-harmful sensations related to exertion as normal and non-threatening by sustained, focused attention on present-moment tasks (Gardner & Moore, 2007, p. 16). This stance likely results in the appraisal of such sensations as less threatening and accepting of normal exertion-related sensations, leading to more accurate RPEs. For example, during RPE-L specific tasks, such as a handgrip endurance task, during which central RPE factors may remain unchanged but lactic acid builds up in the hands, the sensation of burning hand muscles may be non-judged and accepted among more mindful individuals. DePetrillo and colleagues (2009) reported significant increases in decentering (measured by scores on the Toronto Mindfulness Scale [TMS]) in recreational long-distance runners after an MSPE intervention. However, this study employed retrospective self-report mindfulness measures that were designed for non-exercise contexts, such as the TMS, which significantly reduces the validity of their results. Additionally, the authors neglected exploring how decentering influences real-time assessment measures during exercise, such as RPEs, opting only to collect data at baseline and follow-up. Further, the authors failed to measure perceived stress, which could have elucidated participant appraisals of exercise. Non-judgment or decentering may also help mindful individuals differentiate pain from discomfort, as discussed in the following subsection.

Mindfulness may help differentiate pain from discomfort.

Mindfulness encourages non-judging and acceptance of potentially unpleasant stimuli at *non-harmful* intensities by increasing discomfort and pain tolerances (Grant & Rainville, 2009; Kingston, Chadwick, Meron, & Skinner, 2007). Grant and Rainville (2009) assessed pain perception/tolerance in middle-aged “highly trained Zen meditators” (> 1000 hours of meditation practice) by placing a hot device capable of titrating temperatures onto participants’ calves and instructed them to either “…focus your attention exclusively on the stimulation of your left leg” (analogous to association) or “…focus your attention on the stimulation of your left leg. Try not to judge the stimulation but simply observe the stimulation, moment by moment" (analogous to mindful states). Compared to age- and gender-matched controls, highly trained Zen meditators required significantly higher temperatures before reporting moderate pain during the "mindful" condition. Meditators may have coped with the sensations by accurately appraising the stimulus as unlikely to cause injury, thus differentiating transient discomfort from pain likely to cause injury; an important point while rating perceived exertion (Borg, 1998, p. 10). Further, this study may demonstrate how associative states differ from mindful states during exercise, highlighting the importance of non-judgment. The results of this study are impressive with only 13 meditators in the study. The external validity of these results may be limited, however, due to very specific (and relatively unique) sample characteristics (e.g., highly trained Zen meditators).

Overall, mindfulness may increase the frequency of benign (non-judgmental) or positive appraisals, thus reducing perceived stress (Branstrom, Kvillemo, Brandberg, & Moskowitz, 2010; Garland, et al., 2009; Shapiro, Oman, Thoresen, Plante, & Flinders, 2008; Waters, et al., 2009). Mindfulness may also decrease automatic judgments to improve tolerance and acceptance of exertion-related sensations, which could result in more accurate RPEs and less frequent under- or over-exertion. However, there is currently scant research exploring the impact of non-judgment in the context of exercise and there are no published studies which incorporated RPEs. According to the Transactional Model of Stress, after appraisal processing, coping strategies are suggested to occur, which are now reviewed in relation to mindfulness.

Mindfulness may increase adaptive coping strategies.

Kabat-Zinn (1990) proposed that mindfulness improves coping by promoting "responding" (focused, pensive) to a stressor (p. 266). Therefore, mindfulness may increase the accuracy of RPEs and alter present-moment exercise experience by fostering the suspension of judgment of exertion-related sensations as stressful and reducing experiential avoidance. A coping strategy receiving increasing focus in recent RPE research is attentional focus.

Mindfulness may increase adaptive attentional coping strategies.

In the context of coping and exercise, mindfulness-based attentional strategies may heighten awareness of internal *and* external present-moment happenings. Mindfulness may increase RPE accuracy by momentary, non-judgment flexible attentional shifts, depending on the demands of the task (Gardner & Moore, 2004; Salmon, et al., 2010). Attention could then freely vary both in breadth and depth. Moran (1996, p. 235) suggested such "attentional flexibility" illustrates what athletes do naturally.

At lower exercise intensities, mindful attention may foster awareness of local RPE factors and environmental stimuli, such as subtle kinesthetic sensations or changes in environmental conditions. As exercise intensity increases to moderate and high intensity and task demands increase, mindful attention is hypothesized to shift increasingly inward while still noticing external stimuli. This attention may increase awareness of both internal and external factors potentially influencing RPEs. Unfortunately, there are no published studies specifically exploring the influence of mindfulness on coping with sensations related to physical exertion.

In summary, mindfulness has been associated with adaptive, focused coping strategies to stressors. During exercise, mindfulness may facilitate adaptive coping with exertion-related symptoms. Mindfulness may promote flexible attention shifts between internal and external stimuli, with heightened awareness of shifts in exertion. These shifts may lead to immersion in present-moment exercise, with a corresponding increase in sensitivity to exertion-related cues, possibly resulting in more accurate RPEs, similar to those reported in a recent SE study described in the next section.

Mindfulness may increase self-efficacy and RPE accuracy.

Hu et al (2007) demonstrated that higher SE is associated with more gradual (and possibly accurate) increases in RPEs during progressive increases in exercise intensity. However, no data were collected regarding the relationship among RPE-L’s, RPE-C’s, and overall RPEs, which limits an understanding of how SE may increase RPE accuracy. The MAC approach reportedly increases SE (Gardner & Moore, 2007, p. 162). However, little is known about the process behind this increase and there are currently no published studies on this proposition. Hence, research related to increasing the accuracy of RPEs is needed. The following section introduces this current study, used to explore a mindfulness-focused model of RPE mean and accuracy.

CHAPTER II

METHODS

Participants and Procedures

The research protocol was approved by the Institutional Review Board at the University of Louisville prior to data collection. A power analysis (using GPower 3.01.0, Faul, Erdfelder, & Buchner, 2007) was completed to estimate the number of participants needed to detect a medium effect size at a level of .95, using multiple regression analyses. These values were based on a previous study by McAuley and Courneya (1992) which explored the relationship between self-efficacy and RPE, chosen because of the potential relationship between self-efficacy and mindfulness (Greason & Cashwell, 2009).The analysis yielded a projected sample size of 89.

The following eligibility criteria were established for participation in the study: 18-23 years old, able to read and comprehend test instructions and questionnaires in English, engage in at least three sessions of moderate intensity exercise (sufficient to induce sweating) per week, and no probe items endorsed on the Physical Activity Readiness Questionnaire (PAR-Q, Thomas, Reading, & Shephard, 1992). Participants were tested in a university-based exercise physiology laboratory using procedures and following policies mandated by administrative personnel. Typical completion time per participant was 75-90 minutes during the course of a single session.

Participants.

Ninety undergraduate and graduate students recruited from psychology courses at the University of Louisville participated in this study. All participants passed the health screening (i.e., the PAR-Q; Thomas, Reading, & Shephard, 1992), indicating no self-reported potential risk for injury during physical activity (ACSM, 2009).

A summary of demographic information and health behaviors is found in Tables 4 and 5. Participants are primarily undergraduates, distributed fairly well across years in college. Participant BMI was at the high end of the "normal" range (*M* = 24.1, *SD* = 3.49), which is consistent with a physically active, young adult sample. Three participants had BMI greater than 30 ("obese" range) and one participant was below 18.5 ("underweight" range). All were included in the study, based upon self-reported physical health. Participant tobacco use and alcohol consumption summarized in Table 5 suggests low current usage; only two participants reported smoking tobacco daily. Approximately 25% endorsed past tobacco use, and approximately 50% reported drinking alcohol. Overall, self-reported demographic, alcohol, and tobacco information suggest that participants are representative of a self-reported healthy undergraduate sample.

Table 4

Participant Demographic Information

Characteristic	Sample Size (percent)	*M (SD*)	Range
Age (years)	90 (100%)	20.18 (0.15)	18-23
Sex			
Female	58 (64%)	-	-
Male	32 (36%)	-	-
Year in college		-	-
Freshman	19 (21%)	-	-
Sophomore	26 (29%)	-	-

Junior	22 (24%)	-	-
Senior	20 (22%)	-	-
Graduate	3 (3%)	-	-
Height (inches)	90 (100%)	66.93 (3.92)	56.68-78.00
Weight (pounds)	90 (100%)	154.46 (25.77)	100.00-247.00
Body mass index (BMI, kg/m^2)	90 (100%)	24.1 (3.49)	16.98-37.27

Table 5

Notable Self-Reported Health Behaviors

Behavior	Sample Size (*n*, percent)	*M (SD)*, range
Daily smoking (cigarettes)		
Smoking	2 (2%)	One participant (3 cigarettes/day), other provided no data
Non-smoking	88 (98%)	
History of tobacco use		
Endorsed	22 (24%)	-
Denied	68 (76%)	-
Drinking alcohol		
Endorsed	39 (43%)	2.48 (.38), 1-10 (weekends)
Denied	51 (57%	-

Procedures.

Participants meeting inclusion criteria read and signed the Informed Consent form in consultation with a laboratory assistant, after which height and weight were measured. Following this, participants provided basic demographic information and completed a series of paper-and-pencil questionnaires assessing self-efficacy, anxiety, attentional focus, leisure-time exercise, and mindfulness. Next, standardized instructions were provided on how to rate perceived exertion (Borg, 1998) using standardized instruments until comprehension. Once instructions were given to participants, APHR$_{max}$ (208 – 0.7 X age; Tanaka, Monahan, & Seals, 2001) was calculated to serve as an index for adjusting treadmill speed and elevation to standardized exercise intensity across participants.

Participants were fitted with a thoracic HR monitor (Polar Heart Rate Monitor Model 610i) and instructed on use of the treadmill. Next, they were asked to complete the treadmill protocol, comprised of a series of two minute stages in which exercise intensity was gradually increased until slight increases in HR were attained. This protocol was designed to standardize exercise intensity across participants based on real-time changes in HR through moderate exercise intensity (76% APHR_{max}; ACSM, 2009), as measured by percent increases in APHR_{max} for each participant. For example, if 76% APHR_{max} was calculated as 145 beats per minute, this protocol sought to increase HR by 2 to 10% APHR_{Max} or 3 to 15 beats during each exercise stage. This protocol differs from traditional treadmill protocols which uniformly make large, abrupt intensity increases across participants that may obscure individual variations in physiological responses to alterations in intensity. Moreover, by employing pronounced increases in either speed or elevation, traditional treadmill protocols are unlikely to differentiate participants who vary in sensitivity to changes in exertion. To rectify these shortcomings, the current protocol made use of very gradual increases in intensity, hypothetically enhancing the likelihood that only relatively mindful participants would notice such changes, and as a result produce a more gradual, linear RPE pattern. A detailed description of this protocol is found in Appendix 1.

Measures

Medical health and physical fitness measures.

Physical Activity Readiness Form; Revised Version (PAR-Q). The PAR-Q (Thomas, Reading, & Shephard, 1992) is a widely used 7-item self-report inventory designed as a screening tool to assess physical preparedness for physical activity. Probe 7 items cover key factors that might signify the presence of cardiovascular or other health risk factors. Participation in the study required that none of the 7 items was endorsed.

Godin Leisure Time Exercise Questionnaire (GLTEQ). The GLTEQ (Godin & Shephard, 1997) is a 4-item self-report questionnaire designed to identify the mean frequency, duration, and intensity of exercise over a typical seven day period.

Body Mass Index (BMI). BMI is a statistical measure calculated by comparing the relationship between an individual's height (inches) and weight (pounds). It is oftentimes used to estimate an individual's relative weight compared to his/her height and ranges from "underweight" (BMI < 18.5) to "obese" (BMI > 30).

Background Questionnaire. This questionnaire is an 18-item measure designed for this study. Items assess various variables that may affect exercise readiness, including age, smoking tobacco, tobacco use history, and drinking alcoholic beverages.

Mindfulness measures.

The Five Facet Mindfulness Questionnaire (FFMQ). The FFMQ (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006) is a 5-point Likert-type measure with 39-items designed to assess five facets of mindfulness: observing, describing g, acting with awareness, nonreactivity to inner experience, and nonjudging of inner experience. Responses on this measure range from 1 (*never* or *very rarely true*) to 5 (*very often* or *always true*). Each facet comprises a summed subscale score, with a maximum of 35-40, depending on the subscale. Reported internal consistency scores range from Cronbach's Alpha coefficients from .75 to .88 (Van Dam, Earleywine, & Danoff-Burg, 2009).

Ratings of perceived exertion (RPE).

Borg 15-item RPE Scale. The Borg 15-item RPE scale (Borg, 1970) is a widely used subjective, self-report scale of exertion. Responses on this interval scale range from 6 ('no exertion at all') to 20 ('maximal exertion'), indexed to a typical adult male's resting and maximal heart rate, respectively. Multiplying the scale value by 10 determines an approximate corresponding HR; for example, an RPE of 6 coincides with a HR of 60 (6 X 10) (Borg, 1971).

Affect, self-efficacy, and body awareness measures.

These measures were only used in preliminary correlational analyses with RPE mean to identify if it would be necessary to statistically control for them during regression analyses predicting RPE mean.

Exercise Self-Efficacy Scale (ESES). The ESES (McAuley, Lox, & Duncan, 1993) is an 8-item scale designed to assess confidence ratings (ranging from 0% [*not at all confident*] to 100% [*highly confident*]) to exercise at least three times per week at moderate intensity for 40 or more minutes without stopping. Items range from exercising for one week (item 1) to eight weeks (item 8). The ESES has demonstrated good internal consistency ($\alpha = .92$).

Self-Efficacy Walking Duration Scale. This scale (McAuley, Blissmer, Katula, & Duncan, 2000) is a 10-item scale designed to assess respondents' perceived ability to complete walking at incremental 5-minute periods of walking (5 to 40 minutes) at a moderately fast pace, without stopping. Possible responses range in 10-point increments from 0% (*not at all confident*) to 100% (*highly confident*). This scale demonstrated excellent internal consistency from pre- and post-exercise ($\alpha > .95$).

Body Awareness Questionnaire (BAQ). The BAQ (Shields, Mallory, & Simon, 1989) is an 18-item Likert-type self-report measure designed to assess attentiveness to regular body processes, particularly small body changes, with responses ranging from 1 (*not at all true about me*) to 7 (*very true about me*). The BAQ has demonstrated good test-retest reliability (r = .80).

CHAPTER III

RESULTS

This chapter begins with an explanation of procedures used to prepare data for analysis, and details of a quality check to ensure that the treadmill protocol was effective in increasing exertion level in the proposed increments. This is followed by a summary of descriptive statistics for the Godin Leisure Time Exercise Questionnaire (GLTEQ) and the Five-Facet Mindfulness Questionnaire (FFMQ). Next, statistical tests of four primary hypotheses are presented, assessing the relationship between RPEs and mindfulness. Following this, analyses of four secondary hypotheses addressing the relationship between mindfulness and RPE *accuracy* are presented. Finally, a series of supplementary analyses are presented exploring the differences in RPE based upon FFMQ scores during very light to light exercise intensity.

Data Preparation/Initial Analyses

Because of the assumption of normality for data analyzed using parametric statistics (hierarchical regressions, mixed-design analysis of variance [ANOVA]), frequency distributions and statistics of key variables were examined. By calculating descriptive statistics and inspecting frequency distribution of key variables using histograms and box plots, the data were identified as generally normally distributed.

However, BMI was positively skewed with noticeable kurtosis and was logarithmically transformed to create a more normal distribution. In addition, GLTEQ scores were significantly positively skewed and as a result were logarithmically transformed. These variables were transformed to fit the statistical assumption of normally distributed and linear data for parametric analyses.

To control for differing number of stages among participants due to varying HR responses within the proposed range (2-10% increase in $\mathrm{APHR}_{\mathrm{max}}$ within each exercise stage), RPEs from the first, median, and final stages were used for all analyses. If one stage was missing, the remaining stages were entered as the “first” and “final” stages, essentially omitting the “median” stage. If two stages were missing, the remaining stage was entered as the “final” stage. Because proposed analyses aimed to use the first, median, and final stages within each intensity (defined by $\mathrm{APHR}_{\mathrm{max}}$,), if participants had an even number of stages, data between the two median stages were averaged and included as the “median” stage. For example, if a participant attained four stages during moderate exercise intensity, data between the second and third stages were averaged to calculate the “median” stage data.

In order to utilize a single RPE representative of the *overall* perceived exertion during the treadmill protocol, RPE at the end of each two minute stage from the first, median, and final stages during very light to light *(35-45% $APHR_{max}$ up to 63% $APHR_{max}$)* (208 – 0.7 X age; Tanaka, et al., 2001) *and* moderate *(64% $APHR_{max}$ up to 76% $APHR_{max}$)* intensities (total of six values) were averaged for each participant. Next, because variables significantly correlated with RPE mean were controlled during regression analyses to evaluate the independent influence of mindfulness, correlations between RPE mean and key study variables except mindfulness (anxiety, self-efficacy, background questions, etc.) were run. Spearman correlations were used for categorical variables (e.g., tobacco use history, experimenter sex, etc.) and Pearson correlations for continuous variables. No variables were significantly correlated ($p < .05$) with overall RPE mean. Body Mass Index ($r = -.19$, $p = .08$) was the only variable marginally significantly correlated ($p <.10$) with overall RPE mean.

Similarly, because the influence of measured variables often depends on exercise intensity, identical analyses were completed for very light to light and moderate exercise intensity. RPE mean was calculated using RPE at the end of each two minute stage for the first, median, and final stages during very light to light and then again during moderate intensity exercise. Within each intensity, correlations between key variables and RPE mean were run to identify if key variables needed to be controlled during regression analyses. Endorsing a history of tobacco use (but not current use) was significantly positively correlated with RPE mean during very light to light exercise intensity (*rho* = .21, $p = .047$) and was therefore controlled for during all regression analyses involving this exercise intensity.

Procedural quality assessment and stage selection for analyses.

Data from 15 participants were randomly selected and reviewed to ensure that the treadmill protocol was effective in increasing HR between stages by 2-10% APHR_{max}. This procedure revealed that the protocol was closely followed. In an additional attempt to quantify the relationship between HR and RPE during the treadmill protocol, intra-person correlations between HR and RPE were calculated. These correlations revealed significant positive relationships (mean correlation during very light to light exercise intensity: *r* = .90, during moderate exercise intensity: *r* = .84). Also, a review of treadmill speed reflected that most participants (*n* = 80) did not exceed 6.0 miles per hour (mph) (maximum: 8.8 mph). Most participants (*n* = 83*)* did not exceed 3.0% grade (maximum: 4.3%). Further, Figures 1 and 2 display mean HR and RPE, respectively, for all participants using the first, median, and final stages during very light to light and moderate intensity exercise. These figures reflect that HR and RPE both steadily increased during the treadmill protocol (up to the point where a cool-down phase was initiated).

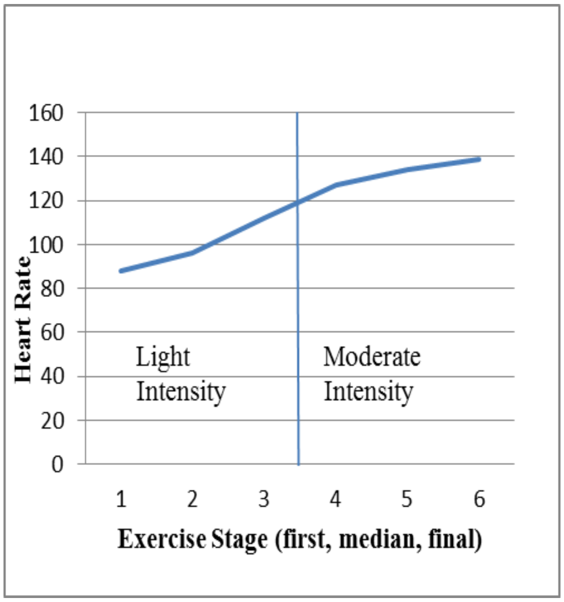


Figure 1. Mean HR during treadmill protocol.

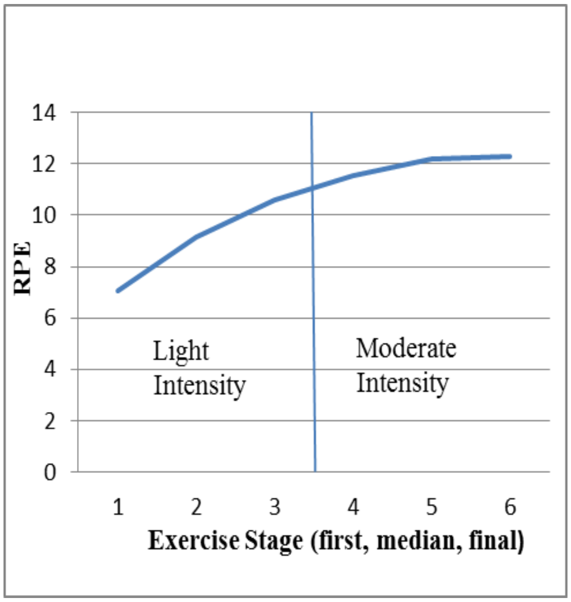


Figure 2. Mean RPE during treadmill protocol.

In addition to the procedures described above, a preliminary qualitative analysis of the treadmill protocol data was conducted to quantify the number of exercise stages attained by participants. This additional analysis was conducted because unexpected differences in the number of stages attained by participants was identified during the previously described quality check. That is, some completed three proposed stages (first, median, final) within each exercise intensity, whereas others completed only two. Frequency statistics for the first, median, and final stages in both exercise intensity ranges are displayed in Table 6. Table 6 contains surprisingly few participants with data during moderate intensity exercise. Only five participants generated data for the first, median and final stages in both very light to light and moderate exercise intensity, suggesting that participants may have responded differently physiologically to the protocol. Unexpected increases in HR exceeding 76% $APHR_{max}$ are thought to be the primary cause of this variability. In contrast, seventy-seven participants produced data points at all three stages during very light to light exercise intensity. Another possible contributory factor may have involved the transition from walking to jogging, which occurred for all participants. For some participants, this resulted in a transition from light intensity (typically below 120 beats per minute) to high exercise intensity (typically more than 145 beats per minute or 77-93% $APHR_{max}$ [ACSM, 2009]), without passing through a moderate intensity phase. This reduced the number of data points from three to two.

Table 6

Frequency of Exercise Stages during the Treadmill Protocol

	Very Light to Light Exercise Intensity	Moderate Exercise Intensity
First Stage	*n* = 90	*n* = 44
Median Stage	*n* = 77	*n* = 5
Final Stage	*n* = 87	*n* = 85

Summary of initial analyses.

The preceding analyses verified that the treadmill protocol was followed, and that HR and RPE were closely correlated within each participant. Unanticipated variations in the number of stages were discovered, with most participants only attaining one or two stages during moderate exercise intensity (opposed to the proposed three). These variations are thought to be due to unexpected, large increases in HR upon jogging. Although many participants only had one or two stages during moderate exercise intensity, proposed statistical analyses were able to be conducted, as explained in the following sections.

Measures Results

Exercise behavior.

Godin Leisure Time Exercise Questionnaire (GLTEQ).

Results from the GLTEQ are shown in Table 7. All participants in this study (*N* = 90) completed the GLTEQ. Descriptive statistics from the GLTEQ suggest that participants in this study reported exercise at least three times per week. Scores from this measure were also used *prior* to completing the treadmill protocol to ensure participants met the inclusion criterion of exercising at least three times per week sufficiently vigorous to induce sweating, which all participants reported.

Table 7

Godin Leisure Time Exercise Questionnaire (GLTEQ) Scores

	Mean	*Standard Deviation*	*Range*
Strenuous (high) intensity			
Frequency (number of sessions/ week)	3.93	1.85	0-12.00
Duration (minutes/session)	54.69	35.11	0-240.00

Moderate intensity			
Frequency (number of sessions/week)	3.00	1.85	0-8.00
Duration (minutes/ session)	37.03	37.27	0-240.00
Mild intensity			
Frequency (number of sessions/week)	3.28	2.77	0-12.00
Duration (minutes/session)	27.03	25.43	0-150.00

Mindfulness.

Five Facet Mindfulness Questionnaire (FFMQ).

A review of FFMQ scores revealed that the data were normally distributed, with a relatively uniform distribution among subscale scores, except that two outliers were identified. Two participants were consistently below the mean on each subscale (2.77-3.58 standard deviations), including the Total Score. To confirm the legitimacy of removing these data as statistical outliers, regression analyses from primary hypothesis 2 were conducted to explore each participant's leverage values, a measure of the influence one value has on the regression model's fit, with leverage values greater than two times the sample's mean requiring review or removal (Li, 1985).

Leverage values of two participants were greater than $2.5(k + 1/n)$, where k equals the number of predictor variables, suggesting that data from these participants excessively impacted the distribution of FFMQ scores. Including these data in analyses was thought to break the statistical assumption of data normality, reducing the validity of results from parametric analyses. Removal of these two data points resulted in FFMQ scores approximating a normal distribution. Deletion of these two cases resulted in a total of 88 participants providing data for subsequent analyses. Descriptive statistics for FFMQ Total and subscale scores for the remaining sample (*n* =88) are presented in Table 8.

Table 8

Distribution of FFMQ Scores

Subscale	*M*	*SD*	Range
Observe	26.92	5.27	13-40
Non-Reactance	22.77	4.71	12-35
Describe	28.99	6.47	19-40
Awareness	26.59	5.66	10-39
Non-Judgment	30.23	5.57	17-40
Total Score (summed)	135.50	16.94	103-135

Testing Primary Hypotheses

For a summary of results for each hypothesis, please see Appendix 2. Detailed results of hypotheses are below. Hypothesis 1 reviews correlational results and Hypotheses 2-4 explain regression analyses results, categorized by exercise intensity.

Hypothesis 1. Total mindfulness scores were predicted to *positively* correlated with RPE. To test this hypothesis, RPE were averaged across all exercise stages, using values obtained at the end of each stage. These values were then correlated with FFMQ scores (Total and subscale scores). Results contradicted this hypothesis, in that mindfulness scores were significantly negatively correlated with RPE.

Table 9 summarizes the correlations between RPE (using RPE at the end of each exercise stages) and FFMQ mindfulness scores. Contrary to predictions, the pattern of results illustrated in Table 9 suggests a statistically significant, but *negative* relationship between RPE and mindfulness, particularly during very light to light exercise intensity. In other words, participants with relatively high overall mindfulness scores produced overall *low* RPEs. Specifically, correlations between overall RPE (means across intensities) and the FFMQ total summed score, *Act with Awareness* and *Describe* subscales were statistically significant ($p < .05$), but opposite the predicted direction. Correlations during moderate exercise intensity were primarily not significant, with the exception of the FFMQ *Non-Judgment* and *Act with Awareness* subscales. No positive correlations of any significance emerged from this analysis.

Table 9

Correlations between RPE and mindfulness for primary hypothesis 1.

RPE (end of each two minute stage)

FFMQ Subscale	_Light Intensity -First Stage_	_Light Intensity- Median Stage_	_Light Intensity - Final Stage_	_Light Intensity –Mean_
Total Score	_r_ = -.10 _p_ = .35 _n_ = 88	_r_ = -21 _p_ = .06* _n_ = 76	_r_ = -.24 _p_ = .03 ** _n_ = 85	_r_ = -.21 _p_ =.05** _n_ = 88
Observe	_r_ = -.16 _p_ = .15 _n_ = 88	_r_ = -.08 _p_ = .48 _n_ = 76	_r_ = -.21 _p_ =.05** _n_ = 85	_r_ = -.16 _p_ = .15 _n_ = 88
Non-Reactance	_r_ = -.01 _p_ = .93 _n_ = 88	_r_ = -07 _p_ = .57 _n_ = 76	_r_ = .01 _p_ = .93 _n_ = 85	_r_ = -.03 _p_ = .80 _n_ = 88
Describe	_r_ = -.18 _p_ = .098 _n_ = 88	_r_ = -.26 _p_ = .03** _n_ = 76	_r_ = -.28 _p_ = .02** _n_ = 85	_r_ = - .25 _p_ = .02 ** _n_ = 88
Act with Awareness	_r_ = -.11 _p_ = .33 _n_ = 88	_r_ = -.22 _p_ = .06* _n_ = 76	_r_ = -.19 _p_ = .09* _n_ = 85	_r_ = -.19 _p_ = .08* _n_ = 88
Non-Judgment	_r_ = .16 _p_ = .14 _n_ = 88	_r_ = .02 _p_ = .86 _n_ = 76	_r_ = -.05 _p_ = .64 _n_ = 85	_r_ = .02 _p_ = .87 _n_ = 88

Note: _p_ < .10*, _p_ < .05**, _p_ < .01.

Table 9 Continued

Correlations between RPE and Mindfulness for Primary Hypothesis 1

	RPE (end of each two minute stage)				
FFMQ Subscale	*Moderate Intensity -First Stage*	*Moderate Intensity - Median Stage*	*Moderate Intensity - Final Stage*	*Moderate Intensity - Mean*	*Overall –Mean*
Total Score	$r = -.25$ $p = .11$ $n = 43$	$r = -.56$ $p = .32$ $n = 5$	$r = -.17$ $p = .13$ $n = 83$	$r = -.20$ $p = .08$* $n = 83$	$r = -.25$ $p = .02$** $n = 88$
Observe	$r = -.16$ $p = .31$ $n = 43$	$r = -.68$ $p = .21$ $n = 5$	$r = -.12$ $p = .28$ $n = 83$	$r = -.12$ $p = .29$ $n = 83$	$r = -.20$ $p = .06$* $n = 88$
Non-Reactance	$r = -.02$ $p = .89$ $n = 43$	$r = -.62$ $p = .26$ $n = 5$	$r = .02$ $p = .87$ $n = 83$	$r = -.11$ $p =.88$ $n = 83$	$r = -.03$ $p = .78$ $n = 88$
Describe	$r = -.18$ $p = .24$ $n = 43$	$r = -.56$ $p = .32$ $n = 5$	$r = -.11$ $p = .32$ $n = 83$	$r = -.14$ $p = .22$ $n = 83$	$r = -.22$ $p = .04$** $n = 88$
Act with Awareness	$r = -.34$ $p = .03$** $n = 43$	$r = -.67$ $p = .22$ $n = 5$	$r = -.21$ $p = .057$* $n = 83$	$r = -.22$ $p = .046$** $n = 83$	$r = -.24$ $p = .03$** $n = 88$
Non-Judgment	$r = -.04$ $p = .81$ $n = 43$	$r = -.89$ $p = .045$** $n = 5$	$r = -.06$ $p = .56$ $n =83$	$r = -.07$ $p = .51$ $n = 83$	$r = -.04$ $p = .72$ $n = 88$

Note: $p < .10$*, $p < .05$**, $p < .01$***

Hypothesis 2. Mindfulness scores were predicted to account for a significant proportion of the variance in RPE mean. To test this hypothesis, RPE values from the end of each stage were averaged across exercise intensities and used as the dependent variable in Hierarchical Regression analyses. These analyses which were chosen to assess the unique contribution of each predictor/independent variable, after controlling for variables in previous regression equations (i.e., “models”). This hypothesis was partially supported.

To control for variables that may be accounting for the relationship between mindfulness and RPE, Hierarchical Regression analyses were run. Body mass index, GLTEQ scores, and experimenter sex were included as control variables, based upon previous research exploring the relationship between RPE and self-efficacy which used regression analyses, such as Pender and colleagues (2002). Initially, FFMQ Total score was used as the mindfulness predictor, followed by identical analyses with FFMQ subscales as the mindfulness predictor.

Within this analysis, each subsequent model adds one variable from the previous model to explore which variable(s) independently account for a significant proportion of the variance in RPE. Table 10 summarizes regression Models 1-4, including the order each variable was added, with the FFMQ Total Score as the mindfulness predictor. The R^2 column displays the percent of variance accounted for by the overall model. For example, .04 equals four percent of the variance accounted). The “Model Sig (*p*)” and “*F* Change Sig (*p*)” columns summarize the overall model significance and the independent significance of each variable, respectively.

Results from Table 10 suggest that FFMQ Total Scores significantly predict RPE mean, with BMI predicting RPE mean approaching statistical significance. To further assess the unique contribution of each variable to the regression models, beta and t-values for new variables in Models 1-4 are presented in Table 11. Overall, BMI predicting RPE mean approached statistical significance in Models 1-3 ($p < .10$). Mindfulness scores (FFMQ Total score) also approached statistical significance ($p = .06$), indicating a potential relationship between mindfulness and RPE, after controlling for other variables previously thought to influence RPE.

Table 10

Summary of Regression Analyses for Primary Hypothesis 2 Using FFMQ Total Score as Mindfulness Predictor (Across Exercise Intensities)

Predictor	Sample Size *(n)*	R^2	*Df* = *F* Value	Model Sig *(p)*	R^2 Change	*F* Change	*F* Change Sig *(p)*
Model 1	88	.04	1, 86 = 3.09	.08*	.035	3.09	.08*
Model 2	88	.04	2, 85 = 1.92	.15	.009	.77	.38
Model 3	88	.05	3, 84 = 1.46	.23	.006	.54	.46
Model 4	88	.09	4, 83 = 2.03	.098	.040	3.61	.06*

Note: $p < .10$* $p < .05$** $p < .01$***

Overall Intensity and Moderate Intensity:

Model 1 = BMI
Model 2 = BMI, GLTEQ
Model 3 = BMI, GLTEQ, Experimenter Sex
Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ Total Score

Table 11

Beta and *T*-statistics for Regression Models 1-4 in Primary Hypothesis 2

Exercise Intensity	Model	Predictor Variable	*β*	*Df*	*T*-statistic	Significance *(p)*
RPE Mean:	1	BMI	-.19	86	-1.76	.08*

light and moderate intensities	2	BMI	-.21	85	-1.90	.06*
		GLTEQ	.10		.88	.38
	3	BMI	-.19	84	-1.72	.09*
		GLTEQ	.10		.89	.38
		Experimenter sex	.08		-.74	.43
	4	BMI	-.17	83	-1.55	.13
		GLTEQ	.06		.57	.57
		Experimenter sex	-.02		-.21	.84
		FFMQ Total Score	-.21		-1.90	.06*

Note: $p < .10$* $p < .05$** $p < .01$***.

Model 4 with FFMQ subscales predicting RPE mean (across exercise intensities).

To explore which aspect of mindfulness may be most predictive of RPE mean, FFMQ subscale scores were substituted for FFMQ Total Score in Model 4. Identical analyses were run with Models 1-3 and Table 12 summarizes Model 4 with FFMQ subscale scores representing mindfulness. Beta and t- values are in Table 13 further explaining the statistical significance of adding each FFMQ subscale score to the existing control variables in Model 4. Notice that the "*F* Change" and "*F* Change Sig" columns illustrate the statistical significance of adding FFMQ subscale scores to the regression model explaining RPE variance, after statistically controlling for variables in Models 1-3. Results displayed in Tables 12 and 13 suggest that the *Describe* and *Act with Awareness* subscales predicting RPE average across intensities approached statistical significance ($p < .10$), after controlling for other influential variables.

Table 12

Summary FFMQ Subscale Scores as Mindfulness Predictor in Regression Model 4 for Primary Hypothesis 2 (Across Exercise Intensities)

FFMQ Predictor	Sample Size (*n*)	R^2	*Df* = *F* Value	Model Sig (*p*)	R^2 Change	*F* Change	*F* Change Sig (*p*)
Observe	88	.07	4, 83 = 1.61	.18	.02	2.03	.16
Non-Reactance	88	.05	4, 83 = 1.09	.37	.001	.06	.81
Describe	88	.08	4, 83 = 1.88	.12	.03	3.06	.08*
Act with Awareness	88	.08	4, 83 = 1.84	.13	.03	2.88	.08*
Non-Judgment	88	.05	4, 83 = 1.11	.36	.001	.12	.73

Note: *p* < .10* *p* < .05** *p* < .01***

Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ Subscale Score

Table 13

Beta and *T*-statistics for FFMQ Subscale Scores in Model 4 as Mindfulness Predictor for Primary Hypothesis 2

Exercise Intensity	FFMQ Predictor	β	*Df*	*T*-statistic	Significance (*p*)
RPE Mean: light and moderate intensities	Observe	-.16	83	-1.42	.16
	Non-Reactance	-.03	83	-.24	.16
	Describe	-.19	83	-1.75	.08
	Act with Awareness	-.19	83	-1.70	.08
	Non-Judgment	-.04	83	-.34	.73

Note: *p* < .10* *p* < .05** *p* < .01***.

Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ Subscale Score

Hypothesis 3. Mindfulness scores were predicted to account for a significant proportion of the variance in RPE during *very light to light* exercise intensity. This hypothesis was not supported. It was tested using Hierarchical Regression Analyses.

A summary of Models 1-5 with FFMQ Total Score representing mindfulness is in Table 14. Tobacco use history was entered in all models because of its significant positive correlation with RPE during very light to light exercise intensity (*rho* = .21, *p* = .047). Table 15 summarizes the beta and t- values for each variable in Models 1-5. These results suggest that tobacco use history, BMI, and experimenter sex significantly predicted RPE mean during very light to light exercise intensity. Mindfulness scores predicting RPE mean failed to attain statistical significance.

Table 14

Summary of Regression Models 1-5 for Primary Hypothesis 3

Predictor	Sample Size (*n*)	R^2	*Df* = *F* Value	Model Sig (*p*)	R^2 Change	*F* Change	*F* Change Sig (*p*)
Model 1	88	.04	1, 86 = 4.90	.03**	.053	4.79	.03**
Model 2	88	.09	2, 85 = 5.65	.01***	.062	5.97	.02**
Model 3	88	.08	3, 84 = 3.73	.02**	.000	.005	.95
Model 4	88	.10	4, 83 = 3.62	.01***	.030	2.96	.09*
Model 5	88	.11	4, 82 = 2.79	.01***	.017	1.71	.20

Note: $p < .10$* $p < .05$** $p < .01$***

Very Light to Light Intensity:
Model 1 = Tobacco Use History
Model 2 = Tobacco Use History, BMI
Model 3 = Tobacco Use History, BMI, GLTEQ
Model 4 = Tobacco Use History, BMI, GLTEQ, Experimenter Sex
Model 5 = Tobacco Use History, BMI, GLTEQ, Experimenter Sex, FFMQ Total Score

Table 15

Beta and *T*-statistics for Regression Models 1-5 for Primary Hypothesis 3

Exercise Intensity	Model	Predictor Variable	β	*Df*	*T*-statistic	Significance (*p*)
RPE Mean: Light intensity	1	Tobacco Use Hx	.23	86	2.19	.03**
	2	Tobacco Use Hx	.24	85	2.32	.02**
		BMI	-.25		-2.44	.02**
	3	Tobacco Use Hx	.24	84	2.29	.02**
		BMI	-.25		-2.39	.02**
		GLTEQ	.007		.07	.95
	4	Tobacco Use Hx	.27	83	2.62	.01**
		BMI	-.22		-2.03	.045
		GLTEQ	.007		.07	.95
		Experimenter sex	-.18		-1.72	.09*
	5	Tobacco Use Hx	.26	82	2.52	.01**
		BMI	-.20		-1.90	.06*
		GLTEQ	-.02		-.14	.89
		Experimenter sex	-.14		-1.29	.20
		FFMQ Total Score	-.14		-1.31	.20

Note: $p < .10$* $p < .05$** $p < .01$***.

Model 5 with FFMQ subscales predicting RPE mean (very light to light exercise intensity).

To explore which facet of mindfulness most significantly predicted RPE mean during very light to light exercise intensity, identical regression models 1-4 from hypothesis 2 were run, followed by replacing FFMQ Total score with FFMQ Subscale scores in Model 5. Table 16 summarizes Model 5 with each FFMQ subscale score predicting RPE and beta and t- values are displayed in Table 17. Results presented in Tables 16 and 17 suggest that the FFMQ *Describe* subscale is the only FFMQ subscale that significantly contributed to the regression model, after controlling for other variables included in Model 5.

Table 16

FFMQ Subscale Scores as Mindfulness Predictor in Model 5 for Primary Hypothesis 3

FFMQ Predictor	Sample Size (*n*)	R^2	*Df* = Value	Model Sig (*p*)	R^2 Change	*F* Change	*F* Change Sig (*p*)
Observe	88	.16	5, 82 = 3.09	.01**	.01	1.28	.26
Non-Reactance	88	.15	5, 82 = 2.79	.02**	.00	.00	.99
Describe	88	.19	5, 82 = 3.77	.004***	.04	4.20	.04**
Act with Awareness	88	.16	5, 82 = 3.05	.01**	.01	1.10	.30
Non-Judgment	88	.15	5, 82 = 2.79	.02**	.004	.34	.56

Note: *p* < .10* *p* < .05** *p* < .01***

Model 5 – Tobacco use history, BMI, GLTEQ, experimenter sex, and FFMQ Subscale scores predicting RPE.

Table 17

Beta and *T*-statistics for FFMQ Subscale Scores as Mindfulness Predictor in Model 5 for Primary Hypothesis 3

Exercise Intensity	FFMQ Predictor	B	*Df*	*T*-statistic	Significance (*p*)
RPE Average: Very light to light intensity	Observe	-.12	83	-1.13	.26
	Non-Reactance	.001	83	.006	.99
	Describe	-.21	83	-2.05	.04**
	Act with Awareness	-.11	83	-1.05	.30
	Non-Judgment	-.06	83	-.58	.56

Note: *p* < .10* *p* < .05** *p* < .01***.

Model 5 – Tobacco use history, BMI, GLTEQ, experimenter sex, and FFMQ Subscale score predicting RPE.

Hypothesis 4. Finally, mindfulness total scores were predicted to account for a significant proportion of the variance in RPE during *moderate* exercise intensity. It was tested using Hierarchical Regression Analyses. RPE from the first, median, and final stages during moderate exercise intensity were used to control the differing number of stages between participants. This hypothesis failed to receive support.

Similar to previous analyses, control variables were entered first in Models 1-3 to explore the unique contribution of mindfulness scores. Table 18 summarizes Models 1-4 with FFMQ total score representing mindfulness, with beta and t- values for each predictor variable displayed in Table 19. Results suggest that no models in this analysis significantly predict RPE mean, indicating that mindfulness may be less influential on RPE mean during moderate exercise intensity.

Table 18

Summary of Regression Models 1-4 for Primary Hypothesis 4 (Moderate Exercise Intensity)

Predictor	Sample Size (*n*)	R^2	*Df* = *F* Value	Model Sig (*p*)	R^2 Change	*F* Change	*F* Change Sig (*p*)
Model 1	82	.01	1, 80 = .52	.47	.006	.52	.47
Model 2	82	.02	2, 79 = .92	.40	.023	1.31	.26
Model 3	82	.02	3, 78 = .64	.59	.024	.12	.74
Model 4	82	.04	4, 77 = .83	.51	.041	1.38	.24

Note: $p < .10$* $p < .05$** $p < .01$***

Model 1 = BMI
Model 2 = BMI, GLTEQ
Model 3 = BMI, GLTEQ, Experimenter Sex
Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ (Total Score)

Table 19

Beta and *T*-statistics for Regression Models 1-4 in Primary Hypothesis 4

Exercise Intensity	Model	Predictor Variable	β	*Df*	*T*-statistic	Significance *(p)*
RPE Mean: Moderate intensity	1	BMI	-.08	80	-.72	.47
	2	BMI	-.11	79	-.96	.34
		GLTEQ	.13		1.15	.26
	3	BMI	-.10	78	-.87	.39
		GLTEQ	.13		1.14	.26
		Experimenter sex	-.04		-.34	.74
	4	BMI	-.09	77	-.75	.46
		GLTEQ	.11		.94	.35
		Experimenter sex	-.001		-.009	.99
		FFMQ Total Score	-.14		-1.18	.24

Note: *p* < .10* *p* < .05** *p* < .01***.

Model 4 with FFMQ subscale scores predicting RPE average (moderate exercise intensity).

Although no significant relationship was identified with the FFMQ Total score, each FFMQ subscale score was included in regression models due to the significant correlation identified in primary hypothesis 1 between FFMQ *Act with Awareness* and *Non-Judgment* subscales and RPE mean during moderate exercise intensity. Identical analyses were run with Models 1-3. Table 20 displays Model 4 with each FFMQ subscale score representing mindfulness (opposed to FFMQ total score), with beta and t- values for each FFMQ subscale score presented in Table 21.

Results from Tables 20 and 21 suggest that *no* FFMQ subscale scores significantly predict RPE average, indicating that mindfulness may be less influential on RPE average during moderate exercise intensity; however, *Describe* and *Act with Awareness* subscales are most predictive of RPE average, albeit statistically non-significant.

Table 20

FFMQ Subscale Scores as Mindfulness Predictor in Model 4 for Primary Hypothesis 4 (Moderate Exercise Intensity)

FFMQ Predictor	Sample Size (*n*)	R^2	*Df* = *F* Value	Model Sig (*p*)	R^2 Change	*F* Change	*F* Change Sig (*p*)
Observe	82	.04	4, 77 = .70	.59	.01	.88	.35
Non-Reactance	82	.02	4, 77 = .48	.75	.00	.01	.91
Describe	82	.04	4, 77 = .83	.51	.02	1.38	.24
Act with Awareness	82	.04	4, 77 = .84	.50	.02	1.42	.24
Non-Judgment	82	.02	4, 77 = .48	.75	.00	.001	.97

Note: $p < .10$* $p < .05$** $p < .01$***

Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ Subscale Score

Table 21

Beta and *T*-statistics for FFMQ Subscale Scores in Model 4 as Mindfulness Predictor for Primary Hypothesis 4

Exercise Intensity	FFMQ Predictor		*Df*	*T*-statistic	Significance (*p*)
RPE average: Moderate intensity	Observe	-.11	77	-.94	.35
	Non-Reactance	.01	77	-.11	.91
	Describe	-.13	77	-1.17	.24
	Act with Awareness	-.14	77	-1.19	.24

Non-Judgment	-.004	77	-.04	.97

Note: *p* < .10* *p* < .05** *p* < .01***.

Model 4 = BMI, GLTEQ, Experimenter Sex, FFMQ Subscale Score

This completes presentation of the analyses used to test the primary hypotheses, concerning the relationship between mindfulness and RPE average. Having established a relationship between mindfulness and RPE, the focus now shifts to a different question during the secondary hypotheses: Does mindfulness (as measured by the FFMQ Total Score) play a role in the *accuracy* of RPEs?

Operationally defining perceived exertion accuracy is a challenging, subjective task. For this study, HR was chosen as a representative index of physical exertion, particularly because of its close relationship with the Borg 15-item RPE scale. The correlation between HR and RPE (multiplied by 10) was predicted to represent objective and subjective exertion, respectively. Further, this correlation was chosen as an index of "RPE accuracy." Hypotheses 1 and 2 in the next section use identical Hierarchical Regression analyses completed in primary hypotheses 2-4 to predict the correlation between RPE (subjective exertion) and HR (objective physical exertion). After this, secondary hypotheses 3 and 4 use a mixed-design ANOVA to explore whether FFMQ Total Scores influence *under*- or *over-rating* RPE, as measured by the difference between measured HR and reported RPE (multiplied by 10).

Secondary Hypotheses

Hypothesis 1. Mindfulness total scores were predicted to i*ncrease* RPE accuracy (correlation between RPE and HR) during *very light to light* exercise intensity *(35-45% $APHR_{max}$ up to 63% $APHR_{max}$)* (208 – 0.7 X age; Tanaka, et al., 2001). A significant association between FFMQ Total scores and RPE accuracy would indicate mindfulness increases RPE accuracy. This hypothesis was not supported. The following steps were used to complete this analysis.

1. To explore the relationship between HR and RPE, Pearson Product Moment correlations were calculated for each participant using HR and RPE at the end of every two minute stage during *very light to light* exercise intensity.

An examination of the correlations between HR and RPE using descriptive statistics identified that the correlations were significantly negatively skewed with noticeable kurtosis. Because of this, the correlations were reflected and then transformed using inverse transformation (1 divided by *r*-value) but remained negatively skewed. Many correlations were very high (r > .90) and were affected by a ceiling effect, with most *r*-values between .8-.9, making it difficult to complete parametric statistical analyses.

2. To assess the relationship between mindfulness and RPE accuracy, the obtained *r* values were correlated with mindfulness scores using Pearson Product Moment correlations.

Mindfulness was not statistically significantly correlated with the correlation between HR and RPE (r = -.02, p = .86).

3. If the correlation between mindfulness and RPE accuracy was significant, it was proposed that Hierarchical Regression analyses identical to those from primary hypothesis 3 would be run to assess the unique contribution of mindfulness scores; however, because FFMQ Total score was not significantly correlated with RPE accuracy, these analyses were not conducted.

Hypothesis 2. Mindfulness scores were hypothesized to predict RPE accuracy (correlation between HR and RPE) during *moderate* exercise intensity *(64-76%* $APHR_{max}$*)*. A significant positive association between mindfulness and RPE accuracy would indicate mindfulness increases RPE accuracy.

This hypothesis was not supported. The following steps were completed to assess this hypothesis with the FFMQ Total Score.

1. To explore the relationship between HR and RPE, Pearson Product Moment correlations were calculated for each participant using HR and RPE at the end of every two minute stage during *moderate* exercise intensity. Descriptive statistics of the correlations between HR and RPE were conducted and identified significant negative skewness and kurtosis. Hence, these correlations were reflected and transformed using inverse transformation (1/ *r*-value) but remained significantly skewed. Thus, the statistical assumption of data normality was broken, limiting the validity of any subsequent results from this hypothesis.

2. The obtained *r* value was correlated with mindfulness scores using Spearman correlations. The obtained correlation was *rho* = -.01, *p* = .95, suggesting no significant relationship between mindfulness and RPE accuracy.

3. Similar to secondary hypothesis 1, if the correlation between mindfulness and RPE accuracy was significant, Hierarchical Regression analyses were proposed to be completed to control variables that may have been accounting for the relationship. However, because the correlation between mindfulness and RPE accuracy was not significant, planned regression analyses were not completed. Further, because the FFMQ

Total Score was not significantly correlated with RPE accuracy, FFMQ subscale scores were excluded from analysis in this hypothesis.

Hypothesis 3. This hypothesis predicted that participants with higher total mindfulness scores would be more likely to accurately rate their exertion level during *v*ery *light to light* exercise intensity (defined as falling within a range of 35% to 63% $\mathrm{APHR}_{\mathrm{ma}x}$), compared to participants with lower total mindfulness scores, who were predicted to *under-rate* their exertion level. This hypothesis was partially supported. To test this hypothesis, the following steps were completed:

1. Each participant's end of stage RPE was multiplied by 10 for first, median, and final stage during *very light to light* exercise intensity. This had the effect of approximating a heart rate value commensurate with the RPE value, as proposed by Borg

2. The value obtained in step 1 was compared to measured HR to obtain difference scores for first, median, and final stages during *very light to light* exercise intensity, a total of 3 values. Positive values indicated *under*-rated RPE while negative values suggest *over-rating*. For example, an RPE rating of 12 would correspond to an estimated HR of 12 x 10 = 120. In the case of a measured HR of 110, the difference (110 – 120 = -10) would suggest an over-rating of exertion, whereas in the case of an obtained HR value of 130, the difference (+10) would suggest that RPE was under-rated. The validity of this assertion depends on the degree to which multiplying RPE x 10 does in fact result in a reasonably accurate estimate of corresponding HR.

3. Total FFMQ mindfulness scores were divided into three groups; low, medium, and high, subsequently referred to as 'tertiles.'

4. Based on the values obtained in steps 2 and 3, a mixed-design Analysis of Variance (ANOVA) was run, using mindfulness grouping as a between-subjects factor and estimated – obtained HR as a within-subjects factor with three values, corresponding to initial, median, and final measurement stages.

FFMQ Total score as between subjects factor.

There was a significant main effect for time for the FFMQ Total score (see Appendix 3 for detailed description). No main effect for mindfulness or interaction effect was identified (see Appendix 3 for detailed description). Table 22 summarizes difference score means and standard deviations for the three levels of mindfulness by three RPE rating stages, reflecting that the *least* mindful group reported the most accurate RPE. Additionally, Figure 3 displays that the least mindful group appear to have reported the most accurate RPE.

FFMQ subscale scores as between subjects factor.

Each FFMQ subscale score replaced the FFMQ Total score and was entered as a between-subjects factor. All results are described in detailed in Appendix 3. The *only* significant main effect of mindfulness involved the FFMQ *Observe* subscale score. These results are summarized in Table 23 and Figure 4, which suggested that mindful observation may influence RPE accuracy, with the most mindful tertile produced the least accurate RPE (under-rated exertion) and the least mindful tertile provided the most accurate RPE (slightly over-rated). Non-significant results for the remaining FFMQ subscales are summarized in Tables 24-27 and Figures 5-8.

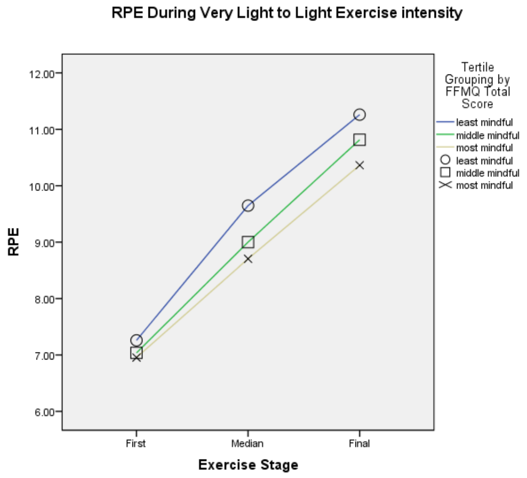
Hypothesis 4. It was predicted that participants with higher FFMQ scores would more accurately rate their exertion during *moderate intensity exercise*, compared to less mindful participants, who were predicted to *over-rate* their exertion levels. Analyses from Hypothesis 3 were repeated using RPE from *moderate* exercise intensity stages. The procedure for testing this hypothesis was similar to that described above for hypothesis 3.

As previously noted, nearly all participants (*n* = 85, 94%) were missing RPE data from the median stage of moderate intensity exercise. This was likely due to the fact that within this range of exertion there tended to be a transition from walking to jogging. To compensate for the limited number of stages, only data from the first and final stages during moderate exercise intensity were included in subsequent analyses.

Using the FFMQ Total score tertiles in this hypotheses, were there was a statistically significant main effect for time, Wilks Lambda = .78, *F* (1, 37) = 10.53, *p* < .01, partial eta squared = .22. There was no statistically significant main effect for mindfulness scores, *F* (2, 37) = .97, *p* = .39, partial eta squared = .05, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. There was a statistically significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .82, *F* (4, 37) = 4.19, *p* = .02, partial eta squared = .19. This interaction indicates a significant influence of mindfulness scores over time, which is illustrated in Figure 9. Table 28 summarizes means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR on the y-axis. No FFMQ subscale scores were entered as between a subjects factor due to the statistically non-significant findings between mindfulness and RPE during moderate exercise intensity during previous analyses.

Supplementary Analyses

Results of the primary hypotheses established a statistically significant, negative relationship between the total FFMQ mindfulness score and RPE. Tests of the secondary hypotheses generally did not reveal a relationship between mindfulness and RPE accuracy. All previous analyses failed to explore differences in RPE *mean* among FFMQ tertiles. To address this, a mixed-design ANOVA was run during supplemental analyses. FFMQ Total scores were entered as the between subjects factor and RPE average from the first, median, and final stages during very light to light exercise intensity were entered as the within subjects factor. Moderate exercise intensity stages were excluded from these analyses due to decreased number of stages. Figure 10 displays that the most mindful tertile appears to have the most gradual increase in RPE. Table 29 summarizes the means and SDs of RPE mean, reflecting that the most mindful tertile reported the lowest RPE.



<u>Figure 10.</u> Mixed-design ANOVA of RPE mean during very light to light intensity (FFMQ Total Score as between subjects factor).

Table 29

<u>RPE Means and Standard Deviations among FFMQ Total Score (Very Light to Light Intensity)</u>

Tertile	First Stage	Median Stage	Final Stage
Least Mindful	*M* = 7.21 *SD* = .92 *n* = 28	*M* = 9.65 *SD* = 1.57 *n* = 28	*M* = 11.26 *SD* = 1.83 *n* = 28
Middle Mindful	*M* = 7.00 *SD* = 1.02 *n* = 32	*M* = 9.00 *SD* = 1.39 *n* = 27	*M* = 10.67 *SD* = 1.77 *n* = 30
Most Mindful	*M* = 7.00 *SD* = .82 *n* = 30	*M* = 8.70 *SD* = 1.45 *n* = 24	*M* = 10.04 *SD* = 1.64 *n* = 30

Results of supplementary analyses suggest that mindfulness *may* result in flatter, more gradual increases in RPE during very light to light exercise intensity. These analyses were primarily meant to provide an assessment of differences in RPE average among stages. Additionally, slopes analyses were not run and no significant differences in RPE average were discovered. Yet, a qualitative review of the data suggests that more mindful participants report smaller increases in RPE between stages during very light to light exercise intensity, potentially indicating greater awareness of small changes in exertion. With the results found from primary, secondary, and supplementary analyses, having suggested that mindfulness influences RPE to some degree, the following chapter summarizes and offers potential explanations of this study's results.

CHAPTER IV

DISCUSSION

This chapter presents a thorough discussion of the current findings and discusses directions for future research. An overview of the study is first presented. Next, potential explanations of primary and secondary hypotheses are introduced, followed by a discussion of results from supplementary analyses. The study's strengths and limitations are then discussed. After this, implications from the current study's results are introduced. Finally, directions for future research are presented.

Overview

Exploring the relationship between mindfulness and RPE is a novel task, warranted by a thorough review of available literature which suggested a potential association between the two concepts. Commonly used treadmill protocols include large, uniform increases in speed and/or grade that are often obvious indications of increased exercise intensity and physical exertion. For example, the Bruce protocol (Bruce, 1971) starts at 1.7 mph and 10% grade and quickly increases speed by .5-1.0 mph and two percent grade until 7.5 mph and 28% incline are attained. A novel treadmill protocol was designed for this study to induce small increases in exercise intensity that may not *necessarily* lead to significant increases in RPE among exercise stages. The protocol employed in this study was hypothesized to increase the chances of identifying participants with heightened awareness of physical exertion. Additionally, this protocol was developed to explore the influence of psychological factors on RPE, particularly mindfulness.

Previous research has suggested that factors increasing present-moment internal awareness increase RPE (Lind, Welch, & Ekkekakis, 2009; Masters & Ogles, 1998). Mindfulness, defined as “present-moment, non-judgmental awareness” (Kabat-Zinn, 1990), was predicted to be positively correlated with RPE. It was also hypothesized that mindfulness would have a significant positive association with RPE, even after statistically controlling for other factors thought to have a relationship with RPE, including BMI or leisure time exercise. Mindfulness was also predicted to increase RPE accuracy (measured by correlation between HR and RPE as well as the difference between HR and RPE).

For the current study, 90 reportedly healthy and physically active university students (18-23 years old) recruited from psychology courses participated in this study. This sample was chosen for ease of data collection, to limit variability in HR caused by age, and to minimize possible medical complications that may affect RPE during exercise (e.g., cardiovascular disease). The sequence of this discussion parallels the Results chapter, beginning with a discussion of the primary and secondary hypotheses.

Primary Hypotheses: Is There a Relationship between Mindfulness and RPE?

Correlational and hierarchical regression analyses were run to assess the relationship between mindfulness and RPE.

Hypothesis 1: An initial relationship between mindfulness and RPE.

Correlational analyses were run to establish an initial relationship between mindfulness and RPE mean during light and moderate exercise intensities. Mindfulness was found to be significantly negatively correlated with RPE, which is opposite of the predicted direction. Using the FFMQ Total Score (a sum of all subscale scores), mindfulness was significantly negatively correlated with RPE mean during light exercise intensity and approached significance during moderate exercise intensity. The FFMQ *Describe* subscale was significantly negatively correlated with RPE mean during light exercise intensity. The FFMQ *Act with Awareness* subscale was also significantly negatively correlated with RPE mean during moderate intensity and approached statistical significance during light exercise intensity. It is interesting that the FFMQ Total Score was significantly negatively correlated with RPE across intensities despite two subscales (*Non-judgment, Non-Reactance*) being non-significantly correlated ($p \geq .70$) with RPE. This suggests that the correlation between RPE and the remaining FFMQ scores was significant enough to maintain a significant correlation. An additional potential explanation may be that the three FFMQ subscales that were significantly correlated with RPE accounted for 24 out of 39 FFMQ questions, contributing approximately 62% of the summed score data

There are several potential explanations for the negative correlations obtained in this phase of the study. For instance, mindfulness may decrease RPE by increasing awareness and acceptance of discomfort (and differentiating from pain) associated with exercise. This explanation is consistent with Grant and Rainville’s (2009) report of increased physical discomfort tolerance by mindfulness meditators. More mindful participants may have appraised the current study’s treadmill protocol as non-threatening due to frequently exercising (based upon GLTEQ scores) and the task's relatively light exercise intensity, enabling them to more adaptively cope with the task by allocating attention to other present-moment stimuli, subsequently reducing RPE.

Overall, in hindsight, it is logical that the FFMQ *Describe* and *Act with Awareness* subscales were significantly related to RPE. Many items within each subscale assess one's perception of how well he/she understands present-moment experience, which may reduce perceived stress expressed as lower RPE. For example, in the *Describe* subscale, one relevant item includes: "When I have a sensation in my body, it's difficult for me to describe it because I can't find the right words" (reverse scored). Similarly, items in the *Act with Awareness* subscale assess attention and distractibility, such as "I find myself doing things without paying attention" (reverse scored). Higher scores on these subscales reflect the perception of being able to sustain present-moment attention as well as confidently (and potentially accurately) describe present-moment experience. Because mindfulness was consistently *negatively* correlated with RPE, mindfulness may function differently than other commonly employed attentional strategies used to cope with the discomfort associated with exercise. In particular, associative strategies, such as intentionally paying attention to one's breathing, are generally thought to increase RPE (for a review, see the section "*Attentional focus as a coping strategy influence RPE accuracy*" of this manuscript).

In an effort to statistically control for variables affecting the relationship between mindfulness and RPE, regression analyses were run in primary hypothesis 2-4.

Hypothesis 2: The relationship between mindfulness and overall RPE mean during light and moderate exercise intensities after controlling for influential variables.

Mindfulness was predicted to remain significantly associated with overall RPE mean (during very light to light *and* moderate exercise intensity) after statistically controlling for other variables thought to predict RPE. Examples of these variables include BMI, experimenter sex, and reported leisure time exercise. After statistically controlling for these variables, mindfulness predicted overall RPE mean approached statistical significance ($p < .10$). In particular, the FFMQ Total score and *Describe* and *Act with Awareness* subscale scores were the most significant. Unfortunately, the variables that were hypothesized to significantly predict RPE mean (experimenter sex, leisure time exercise) were (for the most part) non-significantly predictive of RPE. As a result, statistical significance of the regression models was reduced. Furthermore, there may have been other unmeasured variables accounting for the relationship between mindfulness and RPE mean.

Hypothesis 3: The relationship between mindfulness and RPE mean during very light to light exercise intensity after controlling for influential variables.

After statistically controlling for other variables predicted to affect RPE mean during very light to light exercise intensity (BMI, leisure time exercise, etc.), only the FFMQ *Describe* subscale statistically significantly predicted RPE mean. Higher scores on the *Describe* subscale may reflect the self-perception of accurately describing present-moment experience, decreasing one's confusion about complex internal sensations or processes. Potentially relevant sensations include "burning" in lungs or legs during exercise. With R^2 values less than 20 percent of the variance in RPE, a significant proportion of the variance remained unaccounted for, likely due to unmeasured external or physiological variables, such as participant temperature or respiration rate.

Hypothesis 4: The relationship between mindfulness and RPE mean during moderate exercise intensity after controlling for influential variables.

All mindfulness scores failed to account for a significant proportion of the variance in RPE. In fact, no tested model accounted for a statistically significant proportion of the variance in RPE during moderate exercise intensity. The most influential mindfulness FFMQ subscales appeared to be the *Describe* and *Act with Awareness*, but even those subscales failed to attain statistical significance (p = .24). As even the most significant variable included in this hypothesis (GLTEQ scores), predicted two percent of the variance in RPE, it is apparent that a significant portion of the variance remained unaccounted for. Psychological factors that have been associated with RPE in the past were not correlated with RPE mean in this study, including exercise self-efficacy (Pender, et al., 2002) and anxiety (Morgan, 1968, 1994).

Using the non-significant correlation between all analyzed psychological factors (excluding mindfulness) and RPE mean, it is possible to deduce that physiological variables and procedural variation likely accounted for a significant proportion of the remaining variance in RPE mean. Examples of these physiological variables may include fatigue, blood lactate, and aerobic capacity (Lind, Welch, & Ekkekakis, 2009). Further, regarding procedural variation, the sample size was significantly reduced for analyses in this hypothesis due to a decreased number of participants with two or more stages during this exercise intensity. The reduction in analyzable data decreased statistical power, likely contributing to null results.

Reviewing the results of primary hypotheses.

Primary hypotheses established a relationship between mindfulness scores and RPE mean. Specifically, the FFMQ subscales of *Describe* and *Act with Awareness* were most significantly related to RPE mean during correlational and regression analyses. These subscales were likely most significant because higher scores reflect the perceived ability to accurately describe present-moment experience (*Describe*) and maintaining present-moment awareness and *choosing* to respond (*Act with Awareness*). In the context of this study, higher scores on these subscales potentially indicated noticing, describing, and responding to small changes in physical exertion, resulting in lower RPE. In contrast, lower scores on these subscales likely resulted in decreased awareness of exertion changes until treadmill speed and grade increased to a degree that was more obvious, such as beginning jogging around 4.0-5.0 mph.

The significance of the results from the primary hypotheses declined during moderate intensity exercise. This reduction is consistent with previous research suggesting that psychological factors may be most influential during light intensity exercise, during which the risk of physical injury is relatively minimal (Ekkekakis, 2009; Tenenbaum & Connolly, 2008). In contrast, during moderate or high exercise intensity, physiological variables are thought to most significantly affect RPE. This shift is posited to occur so that exercisers can maintain safety by consciously identifying important changes in bodily processes (Ekkekakis, 2009), including increased HR or burning muscles. Furthermore, these findings are consistent with Ekkekakis (2009) "Dual-Mode

Theory of Affective Responses," which states that cognitive processes (e.g., self-efficacy, personal goals, etc.) are "dominant determinants" of affect and perceived effort during lower levels of exercise intensity. Interoceptive cues (e.g., respiration, body temperature), on the other hand, are more salient during higher exercise intensities. Having established a relationship between mindfulness scores and RPE mean, the next section discusses findings from the secondary hypotheses, addressing the relationship between mindfulness and RPE accuracy.

Secondary Hypotheses: Determining the Relationship between Mindfulness and RPE Accuracy

This section includes a discussion of the results from secondary hypotheses, predicting that mindfulness scores would increase RPE accuracy. Defining RPE accuracy for this study was difficult to do because of the implicit subjectivity within RPE. In an effort to compare objective physical exertion (indexed by HR) and subjective, perceived exertion (RPE), RPE accuracy was defined as the correlation between HR and RPE for each participant. This correlation was then predicted in secondary hypotheses 1 and 2 using hierarchical regression models identical to those used in primary hypotheses 2-4. Mixed-design ANOVAs were run in secondary hypotheses 3 and 4 to explore the possible relationship between mindfulness and *under*- or *over-rating* RPE, defined as the difference between HR and RPE (multiplied by 10). Conducting analyses from secondary hypotheses was dependent upon having established a relationship between mindfulness and RPE mean in the primary hypotheses, which was successful.

Hypothesis 1: The relationship between mindfulness and RPE accuracy during very light to light exercise intensity after controlling for influential variables.

Mindfulness scores were predicted to i*ncreases* RPE accuracy during *very light to light* exercise intensity. Mindfulness, including all FFMQ subscales, failed to predict a significant proportion of the variance in RPE accuracy. The null results may have been due to unconventional statistical analyses. For example, correlating HR and RPE for *each* participant with only up to three data points may have decreased the inter-individual reliability and validity of the data. Although these results are non-significant, related results offer a novel contribution to the extant literature.

Hypothesis 2: The relationship between mindfulness and RPE accuracy during moderate exercise intensity after controlling for influential variables.

Mindfulness scores were predicted to i*ncrease* RPE accuracy during *moderate* exercise intensity. As an initial step in the analytic strategy, FFMQ Total Score was correlated with RPE accuracy. The FFMQ Total score was not significantly correlated with RPE accuracy during moderate exercise intensity. Thus, the proposed Hierarchical Regressions were not completed. Despite attaining non-significant and partially significant results, this strategy was employed as a creative, clinically applicable strategy to measure RPE accuracy and to establish a relationship between mindfulness and RPE accuracy.

Hypothesis 3: The relationship between mindfulness and under- or over-rating RPE during very light to light intensity.

Participants higher in mindfulness scores were hypothesized to report more accurate RPE during v*ery light to light* exercise intensity. Less mindful participants were predicted to *under-rate* their exertion due to failing to notice small changes in physical exertion typical of daily life, such as walking at a moderate pace between 2.5-3.5 mph.

The FFMQ Total score and all FFMQ subscales scores were entered in separate analyses as a between subjects factor in a mixed-design ANOVA. The difference between HR and RPE (multiplied by 10) was entered as the within subjects variable at the first, median, and final stage during very light to light exercise intensity, representing RPE accuracy. No main effect for mindfulness or an interaction effect was found for the Total score or subscale scores, except with the FFMQ *Observe* subscale scores.

There was a significant main effect for the FFMQ *Observe* subscale during these analyses, indicating mindfulness influenced RPE accuracy. The most mindful tertile produced the least accurate RPE (under-rated exertion) and the least mindful tertile provided the most accurate RPE (slightly over-rated). Potential explanations for this non-intuitive result may include mindfully observing contributes to heightened bodily awareness. Many items on the *Observe* subscale focus on increased awareness of external stimuli. For example, two salient items from this subscale include: 1) “I notice the smells and aromas of things,” and; 2) “I pay attention to sounds, such as clocks ticking, birds chirping, or cars passing.”

The perceived ability to mindfully observe present-moment experience may contribute to reduced perceived stress associated with very light to light exercise intensity, resulting in shifting attention to other environmental or social stimuli that may be perceived as more salient. Examples of related stimuli may include focusing on interactions with the research assistant, reducing RPE accuracy.

Hypothesis 4: The relationship between mindfulness and under- or over-rating RPE during moderate intensity exercise.

Participants higher in mindfulness were predicted to report more accurate RPE during *moderate* exercise intensity. Less mindful participants were thought to *over-rate* their exertion due to over-reactivity to increased physical exertion.

There were no statistically significant main effects of mindfulness (FFMQ Total score, all subscales) on RPE accuracy during moderate exercise intensity. These null results suggest that mindfulness score did not significantly influence RPE accuracy. Also, no interaction effect between FFMQ tertiles (low, medium, high) were identified, indicating that mindfulness did not significantly influence RPE accuracy over time.

There are several potential explanations for the current results. These null results may partially be explained by a significantly decreased sample size due to decreased data from stages in the moderate exercise intensity range. Additionally, ratings of perceived exertion may have been less affected by mindfulness (and other psychological variables) during moderate exercise intensity. During this intensity, physiological demands increase (e.g., additional oxygen sent to supply muscles), decreasing the salience of psychological factors. This conceptualization is consistent with previous research that suggested psychological factors are most influential during very light to light exercise intensity (Tenenbaum and Connolly, 2008).

Supplementary Analyses: Differences in RPE Mean among Mindfulness Groups

Mindful participants were predicted to produce a significantly more linear curve across variations in exercise intensities, suggesting greater awareness of small changes in exertion. In particular, mindfulness scores were hypothesized to be most influential during very light to light intensity exercise, where less mindful participants were predicted to ignore exertion changes due to the low physiological demands.

A qualitative review of RPE across intensities illustrated that more mindful participants had a more linear RPE curve (see Figure 10). It is possible that more mindful participants are calibrated differently to task throughout and were more aware of smaller changes in exercise intensity (as designed in the treadmill protocol), resulting in more gradual changes in RPE. This finding is similar to findings by Hu et al (2007) that suggested participants higher in self-efficacy produced flatter, more linear RPE curve. This may be related heightened awareness of changes in present-moment experience.

Summary of results from all analyses.

The results from all analyses conducted in this study suggest that mindfulness and RPE mean are significantly negatively related. Results from the primary hypotheses suggest that the relationship between mindfulness and RPE is most significant during very light to light exercise intensity, and then significantly decreases during moderate exercise intensity. However, during both very light to light and moderate exercise intensities, the *Describe* and *Act with Awareness* FFMQ subscales appear to be most salient. These results suggest that perceiving oneself as capable of accurately describing present-moment experience and choosing to respond thoughtfully decreases RPE.

Regarding the relationship between mindfulness and RPE accuracy, no significant association was found when predicting the correlation between HR and RPE (indexed as RPE accuracy). This null result was likely due to calculating a correlation between only two to three data points. Within regard to RPE accuracy (calculated by the difference between HR and RPE multiplied by 10) using mixed-design ANOVAs, only the FFMQ *Observe* subscale identified an influence between mindfulness and RPE accuracy. Overall, the results from the current study and analytic strategy suggest either no relationship or a limited relationship between mindfulness and RPE accuracy. Having discussed the study's results, the next section will introduce strengths of the study.

Strengths

Topic.

This study's novel exploration of mindfulness in the context of physical exertion is perhaps its greatest strength. An OVID and PsycInfo database search in May 2013 using a combination of "effort, mindfulness, exertion, RPE" resulted in no applicable studies, suggesting that this area remains unexplored. However, an internet search identified several websites, written articles, and blogs promoting the potential relationship between mindfulness and exertion awareness among non-elite athletes (Jenkins, 2013; Tse, 2012), likely indicating a public interest and an intuitive relationship.

Two explanations of the discrepancy between public interest and research publications exploring the relationship between mindfulness and RPE are proposed. First, the relative paucity of research publications can likely partially be attributed to the onerous time required for scientific research, with studies often taking several years to complete. Second, the scant research literature may illustrate the reluctance of Western exercise research to shift from promoting "quick fixes" for weight loss and optimal performance during exerciseto adopting lengthier, methodical practices aimed at enhancing holistic wellness. These practices may include exploring and accepting potentially uncomfortable aspects of one's experience. In the context of exercise, this may include integrating a willingness to experience discomfort related to increased HR or respiration rate. Moreover, a mindful perspective of exertion might emphasize the importance of describing, accepting, and learning from sensations or experiences that are often over-looked or ignored during exercise. For example, accurately identifying and describing discomfort as a normal, healthy component of an exercise session may represent a mindful perspective. Having identified the current topic as a strength, the next section discusses methodological strengths of this study.

Methods.

Procedures and participants.

Designing and employing a treadmill protocol calibrated to each participant's HR response is a major strength of this study. Traditional protocols fail to adjust exercise intensity based upon each participant's physical response, and instead stipulate uniform changes in speed and grade, likely resulting in varied experiences for participants. The current protocol may have helped reveal that the relationship between mindfulness and RPE mean is strongest during very light to light exercise intensity by standardizing exercise intensity across participants through adjusting exercise intensity based upon changes in HR.

The study's relatively largely sample size with a young, reportedly healthy population is another strength. Using this population likely contributed to attaining the projected require sample size, decreased the time needed to complete data collection (approximately 12 months), and minimized risk of exercise related injuries (no reported injuries during data collection). The next section discusses limitations of the current study.

Limitations

Self-Report.

Despite significant strengths, there are several limitations of the current study. For example, there was a general over-reliance upon self-report data, spanning health behaviors, psychological factors, and mindfulness. This reliance may have decreased the validity of the data by introducing the opportunity for participant misinterpretation and subsequent reporting of present-moment experience. Regarding exercise behavior and physical fitness, we were unable identify who was actually physically fit aside from heart rate. Further, although it was managed by the design of the treadmill protocol, there was significant variability in HR response to exercise, likely indicating significant variability in objective physical fitness. Including BMI as an easily measured index of physical fitness and body composition was likely erroneous (despite its frequent application within the literature), as it is harshly critiqued due to its inability to differentiate muscle mass, adiposity, and bone density (Wells, 2001). Additionally, no objective measure was used to ensure participants abstained from drinking alcohol, smoking, eating, or drinking before participating in this study; ideally, an objective test would have been completed to ensure abstinence (e.g., sweat test for alcohol).

A significant limitation of this study involves measuring mindfulness. As noted by Grossman (2011), it remains unclear whether self-report measures, such as the FFMQ, truly assess mindfulness. As a concept with roots in Eastern philosophy and Buddhism, integrating “mindfulness” without a religious component may represent a concept other than mindfulness. Further, social desirability may affect scores on the FFMQ. For instance, participants may report with inaccurately high scores on FFMQ items that are face valid for socially desirable qualities, such as paying attention to others or accepting aspects of daily life. Furthermore, the FFMQ is a measure designed to assess aspects of mindfulness in non-exercise contexts, which may limit the validity of using the FFMQ to explore the relationship between mindfulness and RPE. Regardless, defining mindfulness, remains controversial (Brown, Ryan, Loverich, Biegel, & West, 2011), but it appears that the currently available self-report measures *may* not be the most valid medium to measure mindfulness.

Methods and Results.

Procedures.

Employing a novel treadmill protocol that necessitates careful monitoring of HR as well as treadmill speed and grade may have introduced unexpected variance in treadmill protocol administration. It is noteworthy that although this protocol was designed to induce a similar experience of exercise for all participants, according to research assistant notes, those participants who appeared qualitatively less physically fit based upon physical appearance often had fewer total number of stages because of significant increases in HR. As a study completed in a bustling exercise physiology laboratory, potential environmental distractions were present during testing (e.g., people walking in and out of lab). However, such distractions were infrequently noted by the research assistants and none of the participants reported feeling distracted during testing.

There may have been minimal inter- and intra-individual variance in treadmill protocol administration. Three weeks of rigorous training for research assistants prior to data collection was completed to minimize this variance. Training included: 1) reviewing germane RPE and mindfulness literature; 2) memorizing the treadmill protocol, and; 3) completing the protocol as a test participant (i.e., jogging on treadmill) at least twice and as a research assistant (i.e., administering the protocol to another research assistant) four or more times. Moreover, research assistants were limited to advanced undergraduates (*n* = 1), post-bachelor students (*n* = 2) or graduate students (*n* = 1).

Unaccounted variables.

This study failed to assess the influence of numerous variables that could potentially affect RPE, including academic stressors, sleep deprivation, sexual orientation (Hochstetler, et al., 1985). Also, confusion about identifying the testing location, which was reported by more than 10 participants, may have influenced perceived stress and RPE. Physiological variables (e.g., temperature, pain, respiration rate, blood lactate) that have been linked with changes in RPE (Caraca Smirmaul, 2012; Chen, Fan, & Moe, 2002) were not recorded during this study, largely due to attempting to maintain participant comfort and ease of data collection. Further, we failed to account for medications that may have affected RPE; for example, ADHD medications have been linked with increased HR and RPE (Mahon, Woodruff, Horn, Marjerrison, & Cole, 2012). This analysis was excluded due lack of pharmacological knowledge on the researcher's behalf. It was also unclear what tobacco products participants endorsed using in the past (e.g., chew, snuff, cigars, etc.). Finally, there were significant variations in the time of day for which data were collected, ranging from 9:00 A.M. to 7:00 P.M, which may have affected RPE but was excluded from statistical analyses. Laboratory and research assistant availability necessitated collecting data throughout the day and early evening.

Participants.

Choosing an undergraduate population who received course credit may have resulted in unknown, unexpected variance. For instance, an important sample of participants who may have responded differently than those included in this study were missed due to a “no show” rate of approximately 40 percent. Further, the majority of participants completed the study during either the first or last three weeks of two 16 week semesters, potentially introduced variability in participant characteristics. Data from those participating near the end of the semester *may* have been more influenced by external academic stressors, resulting in increased fatigue, which may have affected present-moment awareness or RPE. Also, employing specific sample of undergraduates reporting as exercising three or more times per week may likely reduces external validity to other groups.

Statistical analyses.

As a novel study exploring the potential relationship between mindfulness and RPE accuracy, several unconventional statistical analyses were used. For example, the Borg 15-item RPE scale (Borg, 1971) was included in regression analyses to predict RPE accuracy, which was discouraged by Borg (1998). Borg (1998) proposed using RPE to *estimate* of physical exertion, opposed to predicting exertion accuracy, because of inter-individual variability in HR responses. Although there may be more advisable strategies and no previous studies using this approach were found, correlating RPE with HR represented a reasonable effort to establish a define RPE accuracy.

Additional, statistically uncontrolled variables may have influenced the data. Examples includes that an uneven number of males and females participated in this study, with females comprising 64% of the participants. However, participant sex is often not significantly correlated with RPE (Springer & Pincivero, 2010), indicating that this study’s data may have not been affected. Experimenter sex was balanced (two females, two males), but females completed approximately 65 percent of the data collection.

Conclusions

This study explored the relationship between mindfulness and RPE in a preliminary manner, using a modified treadmill test to vary the intensity of physical exertion. In an area of research where significant questions remain regarding defining exertion and factors influencing RPE (Caraca Smirmaul, 2009), introducing a variable (i.e., mindfulness) that may have a relationship with RPE is salient to furthering the extant literature. This is a scientifically valuable study that differs from previous mindfulness and exercise studies that have focused on meditative movement (Roland, et al., 2011) or enhancing athletic performance (Eversfield, 2003; Gardner & Moore, 2004, 2007; Gooding & Gardner, 2009).

Results of this study generally suggest mindfulness scores are negatively correlated with RPE mean, particularly during the upper limit of very light to light exercise intensity. The FFMQ *Describe* and *Act with Awareness* subscales are consistently the facets of mindfulness that are most significantly associated with RPE mean. These results indicate that the perception of accurately describing present-moment experience and sustaining attention on present-moment experience influence RPE. However, the current results indicate that mindfulness does *not* significantly influence RPE *accuracy* during this protocol. Because a significant proportion of the variance in RPE mean and RPE accuracy was unaccounted for, it is difficult to identify factors that may have contributed to the current findings. Regardless, the current study’s findings offer significant implications for future research, which are presented in the following section.

Implications

Based upon the findings that mindfulnessis significantly negatively linked with RPE, mindfulness may be an important novel area for future RPE research, with an emphasis on sustained exertion. Possible implications of the current study may be for discomfort tolerance research, such as during long-distance running or cardiac and medical rehabilitation. Utilizing mindfulness as a strategy to decrease RPE may also have implications for weight loss and exercise initiation strategies, potentially making mindfulness and RPE a rich research area for weight loss interventions. Related implications may include psychotherapy, MBSR (yoga), and behavioral activation recommendations.

Future Directions

Mindfulness and acceptance-based approaches continue represent a burgeoning area in sport psychology research (Gardner & Moore, 2012). With new, intriguing results, the current study's findings foster future research, which is discussed in the following section. This section begins with proposed modifications to the current study's treadmill protocol and strategies to adopt the protocol to participant samples with different demographic characteristics. Next, alternative strategies to self-report measures are discussed.

Protocol and participants.

Because only five participants produced data for all three stages (first, median, final) during moderate exercise intensity, there are several options to improve the current protocol and expand the findings to new participant populations. First, the current protocol could increase the upper exercise intensity limit to include high exercise intensity. This would increase the number of median stages and control for the effect of jogging on HR. Altering the protocol to include high exercise intensity may also elucidate whether mindfulness influences RPE mean and accuracy during high intensity. A second option to expand the current study includes minimizing the protocol's exercise intensity range to only include very light to light exercise intensity. This may allow the protocol to be applied to elderly or less physically fit populations. A third option may be replicating the current study with elite athletes, which would increase the number of stages in the moderate exercise intensity range by inducing smaller increases in HR due to their physical fitness. Moreover, regarding the current finding of the negative relationship between mindfulness and RPE, this participant population may be most interested in exploring employing mindful interventions as a strategy to reduce RPE during prolonged physical exertion (e.g., marathons).

Mindfulness and measures.

Future research may *significantly* benefit from employing a mindfulness measure designed for exercise contexts or a more objective measure (e.g., a "mindfulness task). Exploring the factor structure of this measure may assist in reducing reliance on mindfulness questionnaires designed for non-exercise contexts. Exploring aspects of mindfulness (e.g., describing current experience) may also prove worthwhile. Because breathing rate and volume are the only consciously perceived and monitored central factors of RPE (Robertson, 1982), measuring mindfulness or previous mindfulness meditation experience may be an interesting direction for future research. Moreover, designing a mindfulness-based intervention for exercise, particularly including the ability to sustain attention and describe present-moment experience, may allow for longitudinal data collection to assess if mindfulness and/or RPE can be altered. No longer relying upon self-report measures should be conducted in future research, particularly regarding physical fitness. Strategies to more accurately measure physical fitness may include pre-test expiratory gas tasks or body composition (e.g., skin calipers).

Overall conclusions

The current study is the first known study to explore the relationship between self-reported mindfulness and RPE mean and accuracy. Significant, negative relationships between mindfulness and RPE mean were found, while no relationship between mindfulness and RPE accuracy was revealed. As a novel dissertation study, there were significant methodological limitations due to self-report; however, the current study provides a solid empirical base for future mindfulness and RPE research to expand upon.

REFERENCES

Acevedo, E., & Ekkekakis, P. (2001). The transactional psychobiological nature of cognitive appraisal during exercise in environmentally stressful conditions. *Psychology of Sport and Exercise, 2*(1), 47-67.

Acevedo, E., Gill, D., Goldfarb, & Boyer, B. (1996). Affect and perceived exertion during a two-hour run. *International Journal of Sport Psychology, 27,* 286-292.

Acevedo, E., Rinehardt, K., & Kraemer, R. (1994). Perceived exertion and affect at varying intensities of running. *Research Quarterly for Exercise and Sport, 65 (4),* 372-377.

American College of Sports Medicine (ACSM). (2009). *Guidelines for Exercise Testing and Prescription* (8th Ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., et al. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment, 15,* 329–342.

Baer, R., & Krietemeyer, J. (2006). Overview of mindfulness- and acceptance-based treatment approaches. In R. Baer (Ed.), *Mindfulness-Based Treatment Approaches: Clinician's Guide to Evidence Based and Applications*, (pp. 3-27). London, UK: Elsevier.

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13,* 27-45.

Balke, B., & Ware, R. (1959). An experimental study of physical fitness of air force personnel. *U.S. Armed Forces Medical Journal, 10*, 675.

Bandura, A. (1997). *Self-efficacy: The Exercise of Control*. New York: W. H. Freeman and

Company.

Barber, T. (1965). Measuring “hypnotic-like” suggestibility with and without “hypnotic induction”; psychometric properties, norms, and variables influencing response to the Barber Suggestibility Scale (BSS). *Psychological Reports, 16,* (Monofigure Supplement 3).

Barkley, J., & Roemmich, J. (2008). Validity of the CALER and OMNI-Bike ratings of perceived exertion. *Medicine & Science in Sports & Exercise, 40,* 760-766.

Barnes, L., Harp, D., & Jung, W. (2002). Reliability generalization of scores on the Spielberger State–Trait Anxiety Inventory. *Educational and Psychological Measurement, 62,* 603–618.

Bar-Or, O. (1977). Age-related changes in exercise perception. In G. Borg (Ed.), *Physical Work and Effort,* (pp. 255-266). Oxford, UK: Pergamon Press.

Barsky, A. J., & Ahern, D. K. (2004). Cognitive behavior therapy for hypochondriasis: A randomized controlled trial. *Journal of the American Medical Association, 291,* 1464–1470.

Bayles, C., Metz, R., Robertson, F., Goss, J., Cosgrove, & McBurney, D. (1990). Perceptual regulation of prescribed exercise. *Journal of Cardiopulmonary Rehabilitation, 10*, 25-31.

Beck, A., & Steer, R. (1990). *Beck anxiety inventory manual.* San Antonio, TX: The Psychological Corporation.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). Comparison of the Beck Depression Inventories-IA and II in psychiatric outpatients. *Journal of Personality Assessment, 67,* 588–597.

Bernier, M., Thienot, E., Codron, R., & Fournier, J. (2009). Mindfulness and acceptance approaches in sport performance. *Journal of Clinical Sport Psychology, 3(4),* 320-333.

Birnie, K., Garland, S., & Carlson, L. (2010). Psychological benefits for cancer patients and their partners participating in mindfulness-based stress (MBSR). *Psycho-Oncology, 19,* 1004-1009.

Bishop, S. (2002). What do we really know about mindfulness-based stress reduction? *Psychosomatic Medicine, 64*, 71–84.

Bishop, S., Lau, M., Shapiro, S., Carlson, L., Anderson, N., Carmody, J., Segal, Z., Abbey, S., Speca, M., Velting, D., & Devins, G. (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice, 11(3),* 230-241.

Bodner, T., & Langer, E. (2001). Individual differences in mindfulness: The Langer Mindfulness Scale. Poster session presented at the annual meeting of the American Psychological Society, Toronto, Ontario, Canada.

Borg, G. (1971). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine, 2*(2), 92-98.

Borg, G. (1973). Perceived exertion: A note on “history” and methods. *Medicine and Science in Sports, 5,* 90-93.

Borg, G. (1982). A category scale with ratio properties for intermodal and interindividual comparisons. In H.G. Geissler & P. Petzold, *Psychophysical Judgment and the Process of Perception,* (pp. 25-34). Berlin, Germany: VED Deutcher Verlag der Wissenschaften.

Borg, G. (1985). *An Introduction to Borg’s RPE-scale*. Ithaca, NY: Mouvement.

Borg, G. (1990). Psychophysical scaling with applications in physical work and the perception of exertion. *Scandanavian Journal of Work and Environmental Health, 16,* 55-58.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics.

Borg, G., & Dahlstrom, H. (1959). Psykofysisk undersokning av arbete pa cykelergometer. *Nordisk Medicin, 62,* 1383-1386

Borg, G., & Dahlstrom, H. (1960). The perception of muscular work. *Umea Vetensk. Bibiotekskr, 5,* 1-27.

Boutcher, S., & Trenske, M. (1990). The effects of sensory deprivation and music on perceived exertion and affect during exercise. *Journal of Sport & Exercise Psychology, 12,* 167-176.

Branstrom, R., Kvillemo, P., Brandberg, Y., & Moskowitz, J. (2010). Well-being in a stress reduction intervention for cancer patients—A randomized study. *Annals of Behavioral Medicine, 39,* 151-161.

Brock, D., Chandler-Laney, P., Alvarez, J., Gower, B., Gaesser, G., & Hunter, G. (2010). Perception of exercise difficulty predicts weight regain in formerly overweight women. *Obesity, 18(5),* 982-986.

Brown, K.W., & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology,* 84*(4),* 822-848.

Brown, K, Ryan, R., Loverich, T., Biegel, G., & West, A. (2011). Out of the armchair and intro the streets: Measuring mindfulness advances knowledge and improves interventions: Reply to Grossman (2011). *Psychological Assessment, 23 (4), 1041-1046.*

Bruce, R. (1971). Exercise testing of patients with coronary heart disease. *Annals of Clinical Research, 3,* 323.

Cafarelli, E., & Noble, B. (1976). The effect of inspired carbon dioxide on subjective estimates of exertion during exercise. *Ergonomics, 19,* 581-589.

Caldwell, K., Harrison, M., Adams, M., Quin, R., & Greeson, J. (2010). Developing mindfulness in college students through movement-based courses: Effects of self-regulatory self-efficacy, mood, stress, and sleep quality. *Journal of American College Health, 53,* 433-442.

Calogero, R.M., & Pedrotty, K.N. (2007). Daily practices for mindful exercise. In L.L. Abate, D.Embry, & M.Baggett (Eds.), *Handbook of low-cost preventive interventions for physical and mental health: Theory, research, and practice,* (pp.141-160). New York, NY: Springer-Verlag.

Caraça Smirmaul, B. (2012). Sense of effort and other unpleasant sensations during exercise: clarifying concepts and mechanisms. *British Journal of Sports Medicine, 46*, 308-311.

Carlson, L. & Thomas, B. (2007). Development of the Calgary Symptoms of Stress Inventory (C-SOSI). *International Journal of Behavioral Medicine, 14,* 249-256.

Carpenter, L., Tompkins, S., Schmiege, S., Nilsson, R., & Bryan, A. (2010). Affective response to physical activity: Testing for measurement invariance of the physical activity affect scale across active and non-active individuals. *Measurement in Physical Education and Exercise Science, 14,* 1-14.

Centers for Disease Control and Prevention (CDC) (2008). *U.S. Physical Activity Statistics.* Retrieved March 8, 2011, from http://apps.nccd.cdc.gov/PASurveillance/StateSumResultV.asp?CI=&Year=2008&State=0#data.

Chen, M., Fan, X., & Moe, S. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. *Journal of Sports Sciences, 20,* 873-899.

ChiLiving, Incorporated (2010). Retrieved March 15, 2011 from http://www.chirunning.com/.

Coote, D., & Tenenbaum, G. (1998). Can emotive imagery aid in tolerating exertion efficiently? *Journal of Sports Medicine & Physical Fitness, 38,* 344-354.

Corbett, J., Vance, S., Lomax, M., & Barwood, M. (2009). Measurement frequency influences the rating of perceived exertion during sub-maximal treadmill running. *European Journal of Applied Physiology, 106*(2), 311-313.

Cordon, S., Brown, K., & Gibson, P. (2009). The role of mindfulness-based stress reduction on perceived stress: Preliminary evidence for the moderating role of attachment style. *Journal of Cognitive Psychotherapy, 23*, 258-269.

Crewe, H., Tucker, R., & Noakes, T. D. (2008). The rate of increase in rating of perceived exertion predicts the duration of exercise to fatigue at a fixed power output in different environmental conditions. *European Journal of Applied Physiology, 103*, 569-577.

De Petrillo, L., Kaufman, K., Glass, C., & Arnkoff, D. (2009). Mindfulness for long-distance runners: An open trial using Mindful Sport Performance Enhancement (MSPE). *Journal of Clinical Sport Psychology, 3(4),* 357-376.

Derogatis, L.R., Lipman, R.S., & Covi, L. (1973). The SCL–90: An outpatient psychiatric rating scale—Preliminary report. *Psychopharmacology Bulletin, 9*, 13–28.

Dishman, R. (1994). Prescribing exercise intensity for healthy adults using perceived exertion. *Medicine and Science in Sports and Exercise, 26 (9),* 1087-1094.

Dishman, R., Graham, R., Buckworth, J., & White-Welkley, J. (2001). Perceived exertion during incremental cycling is not influenced by the Type A Behavior Pattern. *International Journal of Sports Medicine, 22*, 209-214.

Donath, L., Boettger, S., Puta, C., Wetzig, F., Mueller, H. J., Bar, K-J., & Gabriel, H. (2010). Dissociation of performance parameters at the IAT requires specific exercise recommendations for depressed patients. *Progress in Neuro-Psychopharmacology & Biological Psychiatry 34*, 131-135.

Dreyer, D. (2004). *ChiRunning: A Revolutionary Approach to Effortless, Injury-free Running*. New York, NY: Simon & Schuster.

Durand-Bush, N., Salmela, & Green-Demers, I. (2001). The Ottawa Mental Skills Assessment Tool (OMSAT-3*). *The Sport Psychologist, 15*, 119.

Ekblom, B., & Goldbarg, A. (1971). The influence of physical training and other factors on the subjective rating of perceived exertion. *Acta Physiologica Scandinavica, 83,* 399-406.

Ekkekakis, P. (2003). Pleasure and displeasure from the body: Perspective from exercise. *Cognition and Emotion, 17,* 213-239.

Ekkekakis, P., Hall, E., Van Landuyt, L., & Petruzzello, S. (2000). Walking in (affective) circle: Can short walks enhance affect? *Journal of Behavioral Medicine, 23,* 245-275.

Ekkekakis, P., Hall, E., & Petruzzello, S. (2004). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: Rationale and a case for affect-based exercise prescription. *Preventative Medicine, 38,* 149-159.

Ekkekakis, P., & Petruzzello, S. (1999). Acute aerobic exercise and affect: Current status, problems, and prospects regarding dose-response. *Sports Medicine, 28 (5),* 337-374.

Engel, G. (1977). The need for a new medical model: A challenge for biomedicine. *Science, 196*, 129-136.

Eston, R., Williams, J. (1988). Reliability of ratings of perceived effort regulation of exercise intensity. *British Journal of Sports Medicine*, *22,* 153-155.

Evans, S., Ferrando, S., Findler, M., Stowell, C., Smart, C., & Haglin, D. (2008). Mindfulness-based cognitive therapy for generalized anxiety disorder. *Journal of Anxiety Disorders, 22,* 716-721.

Eversfield, S. A. (2003). *Zendurance: A Spiritual Guide for Endurance Athletes*. Halcottsville, NY: Breakaway Books.

Eysenck, H. & Eysenck, S (1975). *Manual of the Eysenck Personality Questionnaire*. London, England: Hodder and Stoughton.

Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods,* 39 *(2)*, 175-91.

Feldman, G., Greeson, J., & Senville, J. (2010). Differential effects of mindful breathing, progressive muscle relaxation, and loving-kindness meditation on decentering and negative reactions to repetitive thoughts. *Behaviour Research and Therapy, 48,* 1002-1011.

Fitzpatrick, L., Simpson, J., & Smith, A. (2010). A qualitative analysis of mindfulness-based cognitive therapy (MBCT) in Parkinson's disease. *Psychology and Psychotherapy, 83,* 179-192.

Foley, E., Baillie, A., Huxter, M., Price, M., & Sinclair, E. (2010). Mindfulness-based cognitive therapy for individuals whose lives have been affected by cancer: A randomized controlled trial. *Journal of Consulting and Clinical Psychology, 78 (1),* 72-79.

Gamberale, F. (1985). The perception of exertion. *Ergonomics, 28*(1), 299-308.

Gardner, F., & Moore, Z. (2004). A Mindfulness-Acceptance-Commitment-Based Approach to Athletic Performance Enhancement: Theoretical Considerations. *Behavior Therapy, 35*(4), 707-723.

Gardner, F., & Moore, Z. (2007). *The psychology of enhancing human performance:*

The mindfulness-acceptance-commitment (MAC) approach. New York: Springer.

Gardner, F., & Moore, Z. (2012). Mindfulness and acceptance models in sport psychology: A decade of basic and applied scientific advancements. *Canadian Psychology,* 53*(4),* 309-318.

Garland, E., Gaylord, S., & Park, J. (2009). The role of mindfulness in positive reappraisal.

Explore 5(1), 37–44.

Gondoni, L., Nibbio, F., Caetani, G., Augello, G., & Titon, A. (2010). What are we measuring? Considerations on subjective ratings of perceived exertion in obese patients for exercise prescription in cardiac rehabilitation programs. *International Journal of Cardiology, 140*(*2*)*,* 236-238.

Gooding, A., & Gardner, F.. (2009). An investigation of the relationship between mindfulness, preshot routine, and basketball free throw percentage. *Journal of Clinical Sport Psychology, 3*(4), 303-319.

Goss, F., Robertson, R., Haile, L., Krause, M., Nagle, E., & Metz, K. (2010). Identification of a rating of perceived exertion-based warning zone to anticipate graded treadmill test termination. *Perceptual & Motor Skills, 110,* 213-223.

Grant, J., & Rainville, P. (2009). Pain sensitivity and analgesic effects of mindful states in Zen meditators: A cross-sectional study. *Psychosomatic Medicine, 71,* 106-114.

Greason, P., & Cashwell, C. (2009). Mindfulness and Counseling Self-Efficacy: The Mediating Role of Attention and Empathy. Counselor Education and Supervision, 49, 2-19.

Grossman, P., Niemann, L., Schmidt, S., & Walach, H. (2004). Mindfulness-based stress reduction and health benefits: A meta-analysis. *Journal of Psychosomatic Research, 57*, 35-43.

Grossman, P. (2008). On measuring mindfulness in psychosomatic and psychological research. *Journal of Psychosomatic Research, 64,* 405–408.

Grossman, P. (2011). Defining mindfulness by how poorly I think I pay attention during everyday awareness and other intractable problems for psychology's (re)invention of mindfulness: Comment on Brown et al. (2011). *Psychological Assessment, 23,* 1034-1040.

Hall, E., Ekkekakis, P., & Petruzzello, S. (2005). Is the relationship of RPE to psychological factors intensity-dependent? *Psychobiology and Behavioral Strategies, 1365-1873.*

Hamilton M. (1960). A rating scale for depression. *Journal of Neurology and Neurosurgery Psychiatry. 23*, 56–62.

Hardy, C., Hall, E., & Prestholdt, P. (1986). The meditational role of social influence in the perception of exertion. *Journal of Sport Psychology, 8,* 88-104.

Hardy, C., & Rejeski, W. J. (1989). Not what, but how one feels: The measurement of affect during exercise *Journal of Sport & Exercise Psychology, 11*, 304-317.

Hassmen, P., Stahl, R., & Borg, G. (1993). Psychophysical responses to exercise in Type A/B men. *Psychosomatic Medicine, 55,* 178-184.

Hayes, S. C., Wilson, K. W., Gifford, E. V., Follette, V. M., & Strosahl, K. (1996). Experiential avoidance and behavioral disorders: A functional dimensional approach to diagnosis and treatment. *Journal of Consulting and Clinical Psychology, 64*(6), 1152-1168.

Hayes, S.C., Strosahl, K.D., & Wilson, K.G. (1999). *Acceptance and commitment therapy:*

An experiential approach to behavior change. New York, NY: The Guilford Press.

Hays, K. (1999). *Working it Out: Using Exercise in Psychotherapy*. Washington, DC: American Psychological Association.

Heinrich, B. (2001). *Racing the Antelope: What Animals Can Teach Us about Running and Life*. New York, NY: Harper Collins.

Herbert, B., Ulbrich, P., & Schandry, R. (2007). Interoceptive sensitivity and physical effort: Implications for the self-control of physical load in everyday life. *Psychophysiology, 44,* 194-202.

Hetzler, R., Seip, R., Boutcher, S., Pierce, E., Snead, A., & Weltman, A. (1991) Effect of exercise modality on ratings of perceived exertion at various lactate concentrations. *Medicine and Science in Sports and Exercise. 23*:88–92, 1991.

Hochstetler, S. A., Rejeski, W. J., & Best, D. L. (1985). The influence of sex-role orientation on ratings of perceived exertion. *Sex Roles, 12,* 825-835.

Holland, D. (2004). Integrating mindfulness meditation and somatic awareness into a public educational setting. *Journal of Humanistic Psychology, 44,* 468-484.

Holtzheimer, P., Veitengruber, J., Wang, C., Krows, M., Thiede, H., Wald., A., & Roy-Byrne, P., (2010). Utility of the Beck Depression Inventory to screen for and track depression in injection drug users seeking hepatitis C treatment. *General Hospital Psychiatry, 32,* 426-432.

Howley, E. (1976). The effect of different intensities of exercise on the excretion of epinephrine and norepinephrine. *Medicine & Science in Sports, 8,* 219-222.

Hu, L., McAuley, E., Motl, R., & Konopack, J. (2007). Influence of self-efficacy on the functional relationship between ratings of perceived exertion and exercise intensity. *Journal of Cardiopulmonary Rehabilitation and Prevention, 27*, 303-308.

Hutchinson, J., Sherman, T., Martinovic, N., & Tenenbaum, G. (2008). The effect of manipulated self-efficacy on perceived and sustained effort. *Journal of Applied Sport Psychology, 20,* 457-472.

Hutchinson, J., & Tenenbaum, G. (2006). Perceived effort – Can it be considered gestalt? *Psychology of Sport and Exercise, 7,* 463-476.

Hutchinson, J., & Tenenbaum, G. (2007). Attention focus during physical effort: The mediating role of task intensity. *Psychology of Sport and Exercise*, *8*, 233-245.

Jackson, S., & Csikszentmihalyi, M. (1999). *Flow in Sports: The Keys to Optimal Experiences and Performances*. Champaign, IL: Human Kinetics.

Jackson, P., & Delehanty, H. (1995). *Sacred Hoops: Spiritual Lessons of a Hardwood Warrior*. New York, NY: Hyperion.

Jackson, S. A., & Eklund, R. C. (2002). Assessing flow in physical activity: The Flow State Scale-2 and Dispositional Flow Scale-2. *Journal of Sport and Exercise Psychology, 24*, 133–150.

Jam, S., Imani, A., Foroughi, M., Seyedalinaghi, S., Koochak, H., & Mohraz, M. (2010). The effects of mindfulness-based stress reduction (MBSR) program in Iranian HIV/AIDS patients: A pilot study. *Acta Medica Iranica, 48 (2),* 101-106.

Jenkins, Michael (Feb 13, 2013) “Mindfulness and Exercise: how can mindfulness improve your fitness?”

www.bodykineticsmarin.com/blond/big/268201/mindfulness-and-exercise-how-can-mindfulness-improve-your-fitness.

Kabat-Zinn, J. (1990). *Full Catastrophe Living: Using the Wisdom of your Mind to Face Stress, Pain and Illness.* New York: Dell Publishing.

Kaufman, K., Glass, C., & Arnkoff, D. (2009). Evaluation of Mindful Sport Performance Enhancement (MSPE): A new approach to promote flow in athletes. *Journal of Clinical Sport Psychology, 3*(4), 334-356.

Khalsa, S., Rudrauf, D., Damasio, A., Davidson, R., Lutz, A., & Tranel, D. (2008). Interoceptive awareness in experienced meditators. *Psychophysiology, 45 (4)*, 671-677.

Kingston, J., Chadwick, P., Meron, D., & Skinner, T. (2007). A pilot randomized control trial investigating the effect of mindfulness practice on pain tolerance, psychological well-being, and physiological activity. *Journal of Psychosomatic Research, 62*, 297-300.

Kinsman, R., & Weiser, P. (1976). Subjective symptomology during work and fatigue. In E. Simonson & P.C. Weiser (Eds.), *Psychological Aspects and Physiological Correlates of Work and Fatigue* (pp. 336-405). Springfield, IL: Thomas.

Lang P. (1980). Behavioral treatment and bio-behavioral assessment: Computer applications. In Sodowski J., Johnson J., Williams, T. (Eds). *Technology in Mental Health Care Delivery Systems* (pp. 119-137). Norwood, NJ: Ablex.

Lau, M.A., Bishop, S.R., Segal, Z.V., Buis, T., Anderson, N.D., Carlson, L, et al. (2006). The Toronto Mindfulness Scale: Development and validation. *Journal of Clinical Psychology, 62(12)*, 1445-1467.

Lazar, S., Kerr, C., Wasserman, R., Gray, J., Greve, D., Treadway, M., McGarvey, M., Quinn, B., Dusek, J., Benson, H., Rauch, S., Moore, C., & Fisch, B. (2005). Meditation experience is associated with increased cortical thickness. *Ageing, 16 (17),* 1893-1897.

Lazarus, R.S. & Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer Publishing Company.

Li, G. 1985. *Robust regression*. In *Exploring Data Tables, Trends, and Shapes*, ed. D. C. Hoaglin, F. Mosteller, and J. W. Tukey, Wiley.

Lovas, D., & Barsky, A. (2010). Mindfulness-based cognitive therapy for hypochondriasis, or severe health anxiety: A pilot study. *Journal of Anxiety Disorders, 24,* 931-935.

Lubin, B. (1967). *Manual for the Depression Adjective Checklist*. Educational and Industrial Testing Service, San Diego, CA.

Lush, E., Salmon, P., Floyd, A., Studts, J., Weissbecker, I., Sephton, S. (2009). Mindfulness meditation for symptom reduction in fibromyalgia: Psychophysiological correlates. *Journal of Clinical Psychology in Medical Settings, 16,* 200-207.

Mahon, A., Woodruff, M., Horn, M. Marjerrison, A., & Cole, A. (2012). Effect of stimulant medication use by children with ADHD on heart rate and perceived exertion. *Adapted Physical Activity Quarterly, 29, 151-160.*

Masters, K., & Ogles, B. (1998). Associative and dissociative cognitive strategies in exercise and running: 20 years later, what do we know? *The Sport Psychologist, 12,* 253–270.

McAuley, E., & Courneya, K. (1992). Self-efficacy relationships with affective and exertion responses to exercise. *Journal of Applied Social Psychology, 22 (4),* 312-326.

McAuley, E., & Courneya, K. (1994). The Subjective Exercise Experience Scale (SEES): Development and preliminary validation. *Journal of Sport and Exercise Psychology, 16,* 163-177.

McAuley, E., Blissmer, B., Katula, J., Duncan, T. (2000). Exercise environment, self-efficacy, and affective responses to acute exercise in older adults. *Psychology and Health, 15,* 341-355.

McAuley, E., Lox, C., & Duncan, T. (1993). Long-term maintenance of exercise, self-efficacy, and physiological change in older adults. *Journal of Gerontology: PSYCHOLOGICAL SCIENCES, 48 (4),* 218-224.

McNair, D., Lorr, M., & Droppelman, L. (1971). *Profile of Mood States*. Educational and Industrial Testing Service.

McAuley, E., & Mihalko, S. L. (1998). Measuring exercise-related self-efficacy. In J. L. Duda (Ed.), *Advances in Sports and Exercise Psychology Measurement,* (pp. 371-390). Morgantown, WV: Fitness Information Technology.

Meyer, T., Miller, M., Metzger, R., & Borkovec, T. (1990). Development and validation of the Penn State Worry Questionnaire. *Behavior Research & Therapy, 28,* 487-495.

Mihevic, P. (1981). Sensory cues for perceived exertion: A review. *Medicine and Science in Sports and Exercise, 13,* 150-163.

Moran, A. (1996). *The psychology of concentration in sport performers.* Exeter, UK: Psychology Press.

Morgan, W. (1968). Selected psychological and psychomotor correlates of depression in psychiatric patients. *Research Quarterly, 39,* 1037-1043.

Morgan, W. (1969). A pilot investigation of physical working capacity in depressed and nondepressed psychiatric males. *The Research Quarterly, 40,* 859-861.

Morgan, W. (1973). Psychological factors influencing perceived exertion. *Medicine & Science in Sports, 5,* 97-103.

Morgan. W. (1994). Psychological components of effort sense. *Medicine and Science in Sports and Exercise, 26,* 1071-1077.

Morgan, W., Hirta, K., Weitz, G., & Balke, B. (1976). Hypnotic perturbation of perceived exertion: Ventilatory consequences. *American Journal of Clinical Hypnosis, 18,* 182-190.

Morgan, W., & Pollock, M. (1977). Psychologic characterization of the elite distance runner. *Annals of the New York Academy of Sciences, 301,* 382–403.

Morgan, W., Raven, P., Drinkwater, B., & Horvath, S. (1973). Perceptual and metabolic responsivity to standard bicycle ergometry following various hypnotic suggestions. *International Journal of Clinical Experimental Hypnosis, 21,* 86-101.

Nideffer, R. (1976). Test of attentional and interpersonal style. *Journal of Personality and Social Psychology, 34 (3),* 394-404.

Noble, B., & Robertson, R. (1996). *Perceived Exertion*. Champaign, IL: Human Kinetics.

Nyklicek, I. (2011). Mindfulness, emotion regulation, and well-being. In I. Nyklicek, A.J.J.M. Vingerhoets, & M/ Zeelenberg (Eds.), *Emotion regulation and well-being* (pp. 101-118). New York: Springer

O’Loughlin, R.E., & Zuckerman, M. (2008). Mindfulness as a moderator of the relationship between dehydroepiandrosterone and reported physical symptoms. *Personality and Individual Differences, 44,* 1193–1202.

Pandolf, K. (1983). Advances in the study and application of perceived exertion. *Exercise and Sport Sciences Review, 11*, 118-158.

Pandolf, K. (1986). Local and central factor contributions in the perception of effort during physical exercise. In G. Borg & M. Ohlsson, *The Perception of Effort in Physical Work,* (pp. 97-110). London, England: Macmillan Press.

Parfitt, G., & Eston, R. (1995). Changes in ratings of perceived exertion and psychological affect in the early stages of exercise. *Perceptual and Motor Skills, 80,* 259-266.

Pender, N., Bar-Or, O., Wilk, B., & Mitchell, S. (2002). Self-efficacy and perceived exertion of girls during exercise. *Nursing Research, 51,* 86-91.

Pennebaker, J., & Lightner, J. (1980). Competition of internal and external information in an exercise setting. *Journal of Personality and Social Psychology, 39,*165–174.

Raes, F., DeWulf, D., Van Heeringen, & Williams, J. (2009). Mindfulness and reduced cognitive reactivity to sad mood: Evidence from a correlational study and a non-randomized waiting list controlled study. *Behaviour Research and Therapy, 47 (7),* 623-627.

Reed, J. (2005). Acute Physical Activity and Self-Reported Affect: A Review. In A. Clark (Ed.). *Causes, role and influence of mood states*. (pp. 91-113). Hauppauge, NY: Nova Biomedical Books.

Rejeski, W. (1981). The perception of exertion: A social psychophysiological integration. *Journal of Sport Psychology, 3*(4), 305-320.

Rejeski, W. (1985). Perceived exertion: An active or passive process? *Journal of Sport Psychology, 7*(371-378).

Rejeski, W., Hardy, C., & Shaw, J. (1991). Psychometric confounds of assessing state anxiety in conjunction with acute bouts of vigorous exercise. *Journal of Sport & Exercise Psychology, 13,* 65-74.

Rejeski, W., & Thompson, A. (1993). Historical and conceptual roots of exercise psychology. In P. Seraganian (Ed.), *Exercise Psychology: The Influence of Physical Exercise on Psychological Processes,* (pp. 3-38). New York, NY: Wiley Books.

Robertson, R. (1982). Central signals of perceived exertion during dynamic exercise. *Medicine and Science in Sports and Exercise, 14*(5), 390-396.

Robertson, R., Gillespie, R., Hiatt, E., & Rose, K. (1977). Perceived exertion and stimulus intensity modulation. *Perception and Motor Skills, 45,* 211-218.

Robertson, R., Goss, F., Rutkowski, J., Lenz, B., Dixon, C., Timmer, J., Frazee, K., Dube, J., & Andreacci, J. (2003). Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Medicine and Science in Sports and Exercise, 35*(2), 333-341.

Safran, J. & Segal, Z. (1990). *Interpersonal Process in Cognitive Therapy*. New York, NY: Basic Books.

Salmon, P., Hanneman, S., & Harwood, B. (2010). Associative/dissociative cognitive strategies in sustained physical activity: Literature review and proposal for a mindfulness-based conceptual model. *The Sport Psychologist, 24 (2),* 127-156.

Salmon, P., Santorelli, S., Sephton, S., and Kabat-Zinn, J (2008). Intervention elements promoting adherence to Mindfulness-Based Stress Reduction (MBSR) programs in a clinical behavioral medicine setting. In S. Shumaker, J. Ockene, K. Riekert (Eds.), *Handbook of Health Behavior Change*, 3rd Ed.. (pp. 271-286). New York, NY: Springer Publishing Co.

Selye, H. (1950). *The Physiology and Pathology of Exposure to Stress*. Montreal Canada: Acta, Inc.

Shapiro, S., & Carlson, L. (2009). *The Art and Science of Mindfulness: Integrating Mindfulness into Psychology and the Helping Professions*. Washington, DC: American Psychological Association.

Shapiro, S., Carlson, L., Astin, J., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of Clinical Psychology, 62*(3), 373-386.

Shapiro, S., Oman, D., Thoresen, C., Plante, T., & Flinders, T. (2008). Cultivating mindfulness: Effects on well-being. *Journal of Clinical Psychology, 64 (7)*, 840-862.

Shields, S., Mallory, M., & Simon, A. (1989). The Body Awareness Questionnaire: Reliability and validity. *Journal of Personality Assessment, 53 (4),* 802-815.

Shusterman, R. (2008). *Body Consciousness: A Philosophy of Mindfulness and Somaesthetics.* Cambridge University Press, New York, NY.

Smith, R., Smoll, F., & Schutz, R. (1990). Measurement and correlates of sport-specific cognitive and somatic trait anxiety: The Sport Anxiety Scale. *Anxiety Research, 2,* 263-280.

Solomon, E., & Bumpus, A. (1978). The running meditation response: An adjunct to psychotherapy. *American Journal of Psychotherapy, 32 (4),* 583-592.

Spielberger, C. D. (1983). *Manual for the State–Trait Anxiety Inventory (Form Y*). Palo Alto, CA: Mind Garden.

Spence, J., & Helmreich, R. (1978). *Masculinity and Femininity: Their Psychological Dimensions, Correlates, and Antecedents*. Austin, TX: University of Texas Press.

Spielberger, C., Gorsuch, R., & Lushene, R. (1969). *The State-Trait Anxiety Inventory*. Palo Alto, CA. Consulting Psychologists Press.

Springer, B., & Pincivero, D. (2010). Differences in ratings of perceived exertion between the sexes during single-joint and whole-body exercise. *Journal of Sport Sciences,* 28*(1)*, 75-82.

Stetson, B., Rahn, J., Dubbert, P., Wilner, B., & Mercury, M. (1997). Prospective evaluation of the effects of stress on exercise adherence in community-residing women. *Health Psychology, 16,* 515-520.

Tacon, A., & McComb, J. (2009). Mindful exercise, quality of life, and survival: A mindfulness-based exercise program for women with breast cancer. *The Journal of Alternative and Complementary Medicine, 15 (1),* 41-46.

Tanaka, H., Monahan, K., & Seals, D. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology, 37 (1),* 153-156.

Tchissambou, B., Packa Massamba, A., Babela, J., Mabiala M., Kissambou. Mboussa, J., & Senga, P. (2004). The effects of smoking and the degree of nicotine dependence on aerobic capacity in sportsmen. *Revue des Maladies Respiratoires.* 1 *(21),* 59-66.

Teixeira, E. (2010). The effect of mindfulness meditation on painful diabetic peripheral neuropathy in adults older than 50 years. *Holistic Nursing Practice, September/October 2010*, 277-283.

Tenenbaum, G. (2001). A social-cognitive perspective of perceived exertion and exertion tolerance. In R.N. Singer, H.A. Hausenblas, & C.M. Janelle (Eds.), *Handbook of Sport Psychology* (2nd ed., pp. 810–820). Hoboken, NJ: John Wiley & Sons Inc.

Tenenbaum, G., & Connolly, C.T. (2008). Attention allocation under varied workload and effort perception in rowers. *Psychology of Sport and Exercise, 9,* 704–717.

Thomas, P. R., Murphy, S. M., & Hardy, L. (1999). Test of performance strategies: Development and preliminary validation of a comprehensive measure of athletes' psychological skills. *Journal of Sports Sciences, 17*, 697–711.

Thompson, B., & Waltz, J. (2008). Mindfulness, self-esteem, and unconditional self-acceptance. *Journal of Rational-Emotive & Cognitive-Behavior Therapy, 26 (2),* 119-126.

Tophoff, M. (2004). Mindfulness-training: Exploring personal change through sensory awareness. *Constructivism in the Human Science, 9,* 43-52.

Trapnell, P., & Campbell, J. (1999). Private self-consciousness and the five-factor model of personality: Distinguishing rumination from reflection. *Journal of Personality and Social Psychology, 76,* 284-304.

Tse, C. (January 19, 2013). "Mindful exercise: changing your approach to exercise and results!) blitzconditioning.com/mindful-exercise-changing-the-approach-to-exercise-and-results/.

Tuson, K., & Sinyor, D. (1993). On the affective benefits of acute aerobic exercise: Taking stock after twenty years of research. In P. Seraganian (Ed.), *Exercise Psychology: The Influence of Physical Exercise on Psychological Processes* (pp. 80-121). New York, NY: Wiley Books.

Ueda, T., Kurokawa, T., Kikkawa, K., & Choi, T. (1993). Contribution of differentiated ratings of perceived exertion to overall exertion in women while swimming. *European Journal of Applied Physiology, 66,* 196-201.

Van Dam, N., Earleywine, M., & Danoff-Burg, S. (2009). Differential item function across meditators and non-meditators on the Five Facet Mindfulness Questionnaire. *Personality and Individual Differences 47, 516-521.*

Walach, H., Nord, E., Zier, C., Dietz-Waschowski, B., Kersig, S., & Schupbach, H. (2007). Mindfulness-based stress reduction as a method for personnel development: A pilot evaluation. *International Journal of Stress Management, 14 (2),* 188-198.

Wallace, B. A. (2009). *Mind in the Balance: Meditation in Science, Buddhism, and Christianity*. New York, NY: Columbia University Press.

Waters, A., Reitzel, L., Cinciripini, P., Yisheng, L., Marcus, M., Vidrine, J., & Wetter, D. (2009). Associations between mindfulness and implicit cognition and self-reported affect. *Substance Abuse, 30,* 328-337.

Weber, B., Jermann, F., Gex-Fabry, M., Nallet, A., Bondolfi, G., & Aubry, J.-M. (2010). Mindfulness-based cognitive therapy for bipolar disorder: A feasibility trial. *European Psychiatry, 25,* 334-337.

Weinstein, N., Brown, K., & Ryan, R. (2009). A multi-method examination of the effects of mindfulness on stress attribution, coping, and emotional well-being. *Journal of Research in Personality, 43,* 374-385.

Weiser, P., Kinsman, R., & Stamper, D. (1974). Task-specific symptomatology changes resulting from prolong submaximal bicycle riding. *Medicine and Science in Sports and Exercise, 6,* 226-231.

Welch, A., Hulley, A., & Beauchamp, M. (2010). Affect and self-efficacy responses during moderate-intensity exercise among low-active women: The effect of cognitive appraisal. *Journal of Sport & Exercise Psychology, 32,* 154-175.

Wells, J. (2001). A critique of the expression of paediatric body composition data. *Archives of Disease in Childhood, 85 (1),* 67-72.

Williams, J. B. (1988). A structured interview guide for the Hamilton Depression Rating Scale. *Archives of General Psychiatry, 45,* 742–747.

Zung, W. (1965). A self-rating depression scale. *Archives of General Psychiatry, 12,* 63–70

SUPPLEMENTAL TABLES & FIGURES

Table 1

Outcome Summary of RPE and Psychological Factors Research

Author(s)	Participants & Sample Size	Experimental Design and Measures	Experimental Task	RPE Collection Frequency	Outcome(s)
		Affect			
Acevedo, Gill, Goldfarb, & Boyer (1996)	12 adult male distance runners (age ≥ 18 yrs)	Within subjects; Borg 15; FS	70% VO$_2$max on treadmill for 2 hours	• 30 min. intervals	• RPE and FS from 30-120 min. (*r* = -.48, -.59, -.64, -.67, all *p* < .05) • FS ↓ 15 min. before-120 min., *F* (6, 66) = 9.14* •
Boutcher & Trenske (1990)	24 female undergraduates (M_{age} = 19.2, *SD*= 1.53)	Within subjects; Borg 15; FS	3, 6 min conditions of cycling @ 3 intensities	• 90 second intervals	• RPE (listen to music) < RPE (sensory deprivation) at low intensity, *t* (23) = 2.91,** • PA (music) > PA (CC) at moderate intensity, *t* (23) = 2.35**
Parfitt & Eston (1995)	71 undergraduates (high and low active). High-active (18 males, M_{age} = 23.9 yrs, *SD*= 3.5; 19 females, M_{age} = 24.3, *SD* = 5.0) Low-active (16 males, M_{age} = 22.9, *SD* = 1.9; 18 females, M_{age} = 26.6, *SD* = 0.7)	Mixed design; Borg 15; FS	2, 4 min conditions of cycling @ 60 or 90% VO$_2$ max	• 2 min. intervals after start then last 20 sec. of condition	• RPE (women; *M* = 14.95, *SD* = 2.27) > RPE (men; *M* = 14.15, *SD* = 2.05) @ 90% VO$_2$ max, *F* (1, 66) = 5.20* • N.S. diff. of RPEs b/w high- and low-active groups (no p-value reported) • PA (active group; *M* = 1.41, *SD* = 1.99) > PA(low-active group; *M* = -0.13, *SD* = 2.24), *F* (1, 66) = 18.35**

Hardy & Rejeski (1989) Experiment #2	68 undergraduates (35 males, 33 females; no age reported)	Descriptive (paper-and-pencil); Borg 15; FS	Paper-and-pencil estimates of correlation b/w RPE and FS at RPEs of 11, 15, 19	• Not collected	• RPE and FS, *r* = -.56, η^2 = .31***
Hardy & Rejeski (1989) Experiment #3	30 male undergraduates (M_{age} = 19.50, *SD* = 2.06)	Within subjects; Borg 15; FS	3, 4-min. stages @ 30, 60, and 90% age-predicted HR_{max} (220-age)	• 1 min. intervals	• RPE and NA ↑ with exercise intensity • RPE and FS (30% VO_2max), *r* = -.33* • RPE and FS (60% VO_2 max), *r* = -.45* • RPE and FS (90% VO_2 max), *r* = -.55*
Welch, Hulley, & Beauchamp (2010)	24 “low-active” undergraduates and university staff (M_{age} = 23.0 yrs, *SD* = 4.6). 2 conditions (unknown duration (UD); known duration (KD))	Within subjects; Borg 15; FS; 3-item Exercise Self-efficacy scale (RG)	2, 30-min cycling @ 90% VT	• 3 min. intervals	• HR ↑ over time, *F* (4, 92) = 62.35*** • RPE ↑ over time, *F* (4, 88) = 22.94*** • UD condition, positive affect ↓ pre-exercise (*M* = 2.19, *SD* = 1.71) to exercise end (*M* = 0.90, *SD* = 1.89)* • KD condition, N.S. change in affect pre- (*M*= 1.85, *SD* = 2.17) to post-exercise (*M* = 1.65, *SD* = 1.34)* • UD condition, during exercise self-efficacy predicted first half session affect, $\Delta R2$ = .21*

Attentional Focus

Coote & Tenenbaum (1998)	48 female undergraduates (M_{age} = 19.42, SD = 3.60)	RCT (3 conditions; CC(no instructions), relaxation imagery, aggressive imagery; Borg CR10	Endurance: 2 trials of 40-50% maximum handgrip	• 15-second intervals	• Endurance (CC) ↓ from trial 1 (M = 109 seconds) to 2 (M= 105 seconds) • Endurance (relaxation) ↑ from trial 1 (M = 87 seconds) to 2 (M= 121 seconds) • Endurance (aggressive) ↑ from trial 1 (M = 89 seconds) to 2 (M= 182 seconds)
Morgan & Pollock (1977)	19 "world class" runners (11 middle-long distance runners, 8 marathoners) and 8 college middle-distance runners.	Mixed-design; Borg 15	Treadmill jogging up @ 10 mph for 6 min. then @ 12 mph for 6 min	•2 min. intervals	• World class runners used "association" more than other groups • N.S. RPE difference among groups at 6 min, F = 1.59, no p-value reported
Tenenbaum & Connolly, 2008	30 'experienced' collegiate rowers (15 males, M_{age} = 19.7 yrs, SD = 2.1; 15 females, M_{age} = 16.1, SD= 2.4) and 30 'novice' high school rowers (15 males, M age = 16.1, SD = 2.4; 15 females;	Mixed design; Borg CR 10; A/D (RG)	Rowing @ varying intensities from 30-75% Maximal intensity	• 60-second intervals	• Intensity ↑ = RPE ↑* • Intensity ↑= D ↑, F (2, 55) = 183.59, η^2 = .87**

	M_{age} = 16.5, *SD* = 2.3)				
		Personality			
Dishman, Graham, Buckworth, & White-Welkley (2001)	44 adult males (age range = 18-35 yrs); Type A (n = 10) Type B (n = 20) Type X (n = 14)	Mixed design; Borg 15; Coded structure interview to classify personality	• Cycling task at varying intensities up to VO_2peak	• Last 15 seconds of each minute	• RPE (Type A, B, X) = N.S., *F* (2, 38) = 0.0006, *p* = 0.994
Hassmen, Stahl, & Borg (1993)	60 male cross-country runners ((15 >/75%ile on measure of Type A personality; *M* = 6.35, *SD*= 0.32; M_{age} = 36.1 yrs); (15 Type B personality runners (lowest 25%ile on measure of Type A personality; *M* = 3.86, *SD*= 0.51, *M* age = 38.2); 30 “Type X” (26-74%ile on measure of Type A	Mixed design; Borg 15; Bortner scale for Type A Behavior Pattern;	• Running 6 laps on 1000 meter course at self-modulated pace based on instructions to run next lap slower or faster than during a competitive race	• Six intervals after completing each lap	• RPE (Type A) < RPE (Type B) @ “quickest” pace, *p* < .02 • HR (Type A) > HR (Types B, X) at RPE of 11**

	personality; M =5.19, SD= 0.48, M_{age} = 37.3)				
Morgan (1973) Exp. #2	Adult Males (no details described)	Within subjects; Borg 15; EPI	Cycling @ varying intensities	• Not reported	• Extraversion and RPE increased negative correlation with ↑ exercise intensity, r = -.62 (moderate intensity), r = -71 (high intensity)
		<u>**Self-Efficacy (SE)**</u>			
Hu, McAuley, Motl, & Konopack (2007)	193 “sedentary” (lack of regular exercise in previous 6 months) older adults (137 women, 56 men; M_{age} = 66.7 yrs, no SD reported)	Within-subjects; Borg 15; Walking SE Scale (RG)	Treadmill jogging up to 100% VO_2peak	• 2 minute intervals	• SE and linear growth function (β = .44*) • SE and quadratic growth function (β = -.63*) • SE predicted constant (more linear) rate of RPE change, lower SE rate of RPE change
Hutchinson, Sherman, Martinovic, & Tenenbaum (2008)	72 undergraduates (39 females, 33 males; M_{age} = 19.18 yrs, SD = .74)	RCT (high-efficacy, low-efficacy, or CC); Task-Specific SE Scale (RG); Verbal report of RPE	Endurance: 25% maximal handgrip	• 15-second intervals	• Endurance (high-efficacy; M = 173.29 seconds, SD = 47.19) > Endurance (low-efficacy; M= 133.75 seconds, SD= 48.87), ES = 0.83*
McAuley & Courneya (1992)	88 middle-aged adults (46 females, 42 males; M age = 53.45 yrs, SD =	Exploratory; SE Scale (RG) Borg 15	Cycling for one min. after 70% age-predicted MHR attained	• 2 minute intervals	• Pre-exercise SE X RPE, r = .38, p < .05

	5.8)				
McAuley, Blissmer, Katula, & Duncan., (2000)	80 sedentary, older adults (lack of regular exercise in previous 6 months) (125 females, 40 males; *M* $_{age}$ = 65.6 yrs)	RCT; Exercise Self-efficacy Scale (ESES; RG); SEES	2 conditions (mall walking or stretching/toning); group or alone setting; 3 intensities (low, moderate, maximal)	•Not described	• In group-light condition, SE improved positive well-being (β = 0.40, $p < .05$) • In alone-maximal condition, SE improved positive well-being (β = 0.40**) and less reported fatigue (β = 0.30*)
Pender, Bar-OR, Wilk, & Mitchell (2002)	103 girls (Age range = 8-17 yrs)	Within subjects; Borg 15; ESES	Cycling for 20 min at 60% VO_2peak; 2 sessions	•4-min intervals from 4-20 min during exercise (averaged for analyses)	• Pre-exercise SE and RPE, r = -.41***
		<u>Social Influence</u>			
Hardy, Hall, & Prestholdt (1986) Experiment #1	9 "untrained" undergraduates from physical education courses (*M* $_{age}$ = 18.70, *SD*= .97)	Within subjects; Borg 15	3, 15 min. trials of cycling @ 25% (light intensity), 50% (moderate intensity) , 75% VO_2max (heavy intensity); All conditions repeated with co-actor or alone	• 3 intervals; once at each intensity	• RPE ↓(co-actor; *M* = 7.9) < RPE (alone; *M* = 9.0) at light intensity, *F*(1, 32) = 6.28* • RPE ↓ (co-actor; *M*12.5) < RPE (alone; *M*= 14.1) at moderate intensity, *F*(1, 32) = 12.81*** • N.S. (RPE) between co-actor and alone at heavy intensity, *F* (1, 32) = .67, *p*> .10
		<u>Psychopathology</u>			
Donath et al. (2010)	15 female participants diagnosed with MDD	Mixed design; BDI;	Cycling @ varying intensities until exhaustion	• Not reported, except a minimum of 5 times at	• Blood lactate* (MDD) > Blood lactate (Controls) at various

	(M_{age} = 38 yrs, SD = 12) 15 matched controls (Mage = 38 yrs, SD= 12)	Borg 15; HAM-D; Age-predicted HRmax (220-age * 0.8); Structured clinical interview		varying intensities	intensities, F = 6.63**) • Suggests MDD participants > physiological responses to exertion than controls • N.S. maximum RPE (MDD) versus controls, F= 3.4*
Morgan (1969)	17 adult hospitalized depressed males (M_{age} = 36 yrs, SD = 11.35)	Zung's Self-Rating Depression Scale	Cycling @ 50 rpm at constant workload up to 150 beats/min HR	• Not collected	• Cycling time (depressed) < Cycling time (non-depressed), U = 5, $p < .001$ • Depression and work capacity, r = -.50*
Morgan (1973) Experiment #1	Not reported	Within-subjects; Magnitude Estimation* (RPE); LDAC; STAI	Cycling @ varying intensities	• Not reported	• ↑ perceptual errors at moderate intensities by "anxious" or "depressed" participants (no statistics reported)
Morgan (1973) Experiment #3	9 males (no ages reported)	Within-subjects; RPE; STAI	Cycling @ varying intensities	• Once post exercise	• RPE and state anxiety, r = .70, (no p-value reported) • RPE and trait anxiety, r = .70, (no p-value reported)
		Sex-role Typology (Masculine-feminine)			
Hochstetler, Rejeski, & Best (1985)	33 female undergraduates (11 "masculine, 11 "feminine",	Mixed design; Borg 15; PAQ	Up to 70% VO$_2$max on treadmill	• 5 min. intervals	• RPE (feminine group) > RPE (masculine, androgynous) from 15-30 min., F (2, 29) = 3.69*

	11"androgynous")				
		Suggestion			
Morgan, Hirta, Weitz, & Balke, (1976)	5 males undergraduates scoring 70%ile on suggestion measures (no age reported)	Within Subjects; BSS	Cycling @ constant intensity for 20 min. on 4 trials	- Not reported	- Participants listened to tape recording suggesting riding at varying grade (incline) - RPE highest in "Uphill" condition, *F* = 7.87**

Outcome Summary of Psychological Factors and RPE Studies

Note. * *P* < .05, ** *p* < .01, *** *p* < .001

Table of Acronyms
VO_2peak = Almost maximal oxygen uptake
@ = At
A = Association
A/D = Association/Dissociation
B/W = between
BDI = Beck Depression Inventory
Borg 15 = Borg 15-item RPE Scale (Borg, 1970, 1973)
Borg CR 10 = Borg Category-Ratio 10-item RPE Scale
BSS = Barber Suggestibility Scale (Barber, 1965)
CC = Control Condition
D = Dissociation
EPI = Eysenck Personality Inventory (Eysenck & Eysenck, 1975)
ESES = Exercise Self-efficacy Scale (McAuley & Mihalko, 1998)
FS = Feeling Scale (affect; Hardy & Rejeski, 1989)
HAM-D = Hamilton Rating Scale for Depression (Hamilton, 1960)
HR = Heart Rate
LDAC = Lubin's Depression Adjective Checklist (Lubin, 1967).
MDD = Major Depressive Disorder
Min = Minutes
MPH = Miles Per Hour
N.S.= Non-significant
PA = Positive Affect
PAQ = Personal Attributes Questionnaire (sex-role orientation measure; Spence & Helmreich, 1978)
RCT = Randomized Controlled Trial
RG = Researcher Generated
SD = Standard Deviation
SE = Self Efficacy
SEES = Subjective Exercise Experiences Scale (McAuley & Courneya, 1994)
STAI = State-Trait Anxiety Inventory (Spielberger Gorsuch, &

Lushene

VO_2max = Maximal Oxygen Uptake

VT = Ventilatory Threshold

Yrs = Years

Table 2

Outcome Summary of Recent Mindfulness-based Interventions in Non-Exercise Contexts

Author(s)	Participants & Sample Size	Experimental Design, Length (weeks), and Conditions	Assessment Measures	Data Collection Frequency	Outcomes
		Mindfulness-based Stress Reduction (MBSR) program			
Birnie, Garland, & Carlson (2010)	Cancer patients (any type) and partners (21 couples, M_{age} = 62.9 yrs, *SD* = 7.37)	Within-subjects 8-week MBSR	• C-SOSI • MAAS • POMS	• Pre- post	• MAAS (patients and partners) ↑ pre-post, *F* (1, 40) = 6.10* • Muscle tension (C-SOSI) ↓ pre-post, *F* (1, 36) = 10.07** • Upper respiratory symptoms (C-SOSI) ↓ pre-post, *F* (1, 36)= 8.11** • POMS (partner) and C-SOSI (patient), *r* = 0.457*
Jam, et al. (2010)	6 HIV positive Iranian patients (M_{age} = 35 yrs, *SD*= 7.7)	Within-subjects; 8-week MBSR	• CD4 Count (disease progression measure) • SCL-90	• Pre- post (after MBSR, 3, 6, 9, 12-month follow-ups)	• CD4 Count ↓ pre-post (all follow-ups) * • SCL-90 ↓ pre-post (12-month follow up), (no *T*-statistic reported*
Lush, et al., (2009)	43 Adult Females with Fibromyalgia (M_{age} = 44.31 yrs, *SD* = 11.25)	Within-subjects; 8-week MBSR (3 groups)	• Psychophysiological recordings	• Pre- post	• Reduced basal SCL activity, *t* = 3.298** • Reduced SCL activity during meditation, *t* = 4.389***
Shapiro, Oman, Thoresen, Plante, & Flinders,	47 Undergraduates (age range 18-24 yrs)	RCT (8 weeks): 1) MBSR (n = 15) 2) Eight Point Program	• MAAS • RRQ	• Pre- post	• MAAS increases (MBSR) > MAAS increase (control) (*M* = 13.43*) • MAAS (MBSR)

(2008)		(EPP) (n = 14) 3) Waitlist control (n = 15)			↓ stress, b = -0.22,** • MAAS (MBSR) ↓ RRQ, b = -0.33,**
		Extraneous			
Teixeira (2010)	20 Diabetics with Neuropathy (M_{age} ≥ 50 yrs; convenience sample)	RCT (4 weeks): 1) Guided mindfulness meditation on compact disc 5x/week (n = 10) 2) Control (completed daily food diary, n = 10)	• Neuropathy-Specific Quality of Life Tool	• Pre-post	• N.S. diff. on overall QOL between groups at 4-week follow-up, *F* (1, 17) = 1.67, *p* > .10, $\eta = 0.05$
		Mindfulness-based Cognitive Therapy (MBCT)			
Evans, et al. (2008)	11 participants with GAD (5 males, 6 females; *M* age = 49, age range = 36-72)	Within-subjects; 8-week MBCT	• BAI • BDI • MAAS	• Pre-post	• BAI ↓ (pre-EOT), *z* score = -2.5*** • BDI ↓ (pre-EOT), *z* score = -1.4*
Foley, Baillie, Huxter, Price, & Sinclair (2010)	115 cancer patients (26 males, 89 females; M_{age} = 55.18 yrs, *SD* = 10.60)	RCT; 1) 8-week MBCT (n = 55) 2) Wait-list control (n = 60)	• HAM-D • FMI	• Baseline • 4-month FU	• MBCT depression improvements > Control depression improvements, *F* (1, 66) = 18.78*** • FMI(MBCT) > FMI (control), *F* (1, 115) = 18.51***
Fitzpatrick, Simpson, & Smith (2010)	12 Parkinson's patients (7 males, 5 females; M_{age} = 66.3 yrs, *SD* = 7.3)	Within-subjects (Descriptive); 8-week MBCT	• Semi-structured clinical interview	• Pre-post	• Increased active coping • Reduced avoidance • Increased sense of group support (within MBCT)

Lovas & Barsky (2010)	10 adults with "hypochondriasis or severe health anxiety" (5 males, 5 females; M_{age} = 35.6 yrs, range = 25-59)	Within-subjects; 8-week MBCT	• BDI • FFMQ • HCQ	• Baseline • EOT • 3-month FU	• BDI ↓ pre – EOT, (z score = -2.40*) • FFMQ ↑ pre-EOT, (z score = 2.19*) • Hypochondriacal thought frequency ↓ (pre-EOT), (z score = -2.60**) • Hypochondriacal thought believability ↓ (pre-EOT), (z score = -2.55*)
Weber, et al. (2010)	15 Bipolar outpatients (median age = 48, range = 37-63 yrs): Type I (n = 6) Type II (n = 8) NOS(n = 1)	Within-subjects; 8-week MBCT	• BDI • KIMS	• Baseline • EOT • 3-month FU	• BDI and KIMS (baseline), r_s = -0.59* • KIMS predicted BDI score (baseline-EOT), r_s = -0.80**

Note. * $P < .05$, ** $p < .01$, *** $p < .001$

Acronym Key
BAI = Beck Anxiety Inventory (Beck & Steer, 1990)
BDI = Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996)
C-SOSI = Calgary Symptoms of Stress Inventory (Carlson & Thomas, 2007)
EOT = End of Treatment
FMI = Frieburg Mindfulness Inventory (Walach, et al., 2006)
FFMQ = Five Fact Mindfulness Questionnaire (Baer, et al., 2008)
FU = Follow-up
GAD = Generalized Anxiety Disorder
HAM-D = Hamilton Rating Scale for Depression (Williams, 1988)
HCQ = Hypochondriacal Cognitions Questionnaire (Barsky & Ahern, 2004)
KIMS = Kentucky Inventory of Mindfulness Skills (Baer, Smith, & Allen, 2004)
M = mean
MAAS (Brown & Ryan, 2003)
POMS = Profile of Mood States (McNair, Lorr, & Droppelman, 1971)
QOL = Quality of life
RCT = Randomized Controlled Trial
RRQ = Rumination and Reflection Questionnaire (Trapnell & Campbell, 1999)
SCL = Electrodermal
SCL-90 = Derogatis Symptom Checklist 90 (Derogatis,

Lipman, & Covi, 1973)
N.S. = Non-Significant
NOS= Not Otherwise Significant

Table 3

Outcome Summary of Mindfulness in the Contexts of Physical Activity and Exercise

Author(s)	Participants and Sample Size	Intervention	Number of sessions; Themes/Components	Measures	Outcome(s)
		Mindfulness-Acceptance-Commitment Approach (MAC)			
Bernier, et al. (2009) Experiment #2	7 elite young golfers (5 males, 2 females; M_{age} = 15.67 yrs, *SD*= 0.74)	Mindfulness and Acceptance Program; Adapted from MBCT and ACT	4 sessions integrating; I. Mental skills training (goal setting, imagery, concentration, relaxation) II. Mindfulness training (focus on breathing, bodily sensations, and movements non-judgmentally) III. Body scan on MP3 player (2x/week) IV. ACT metaphors to teach mindfulness skills	OMSAT-3	•All golfers improved national ranking •4 participants reported mindfulness aided awareness •Golfers were more "activated" (psychologically, physiologically) on the OMSAT-3 compared to controls (not described), *F* (1, 10) = 6.63, *d* = 1.72*
Gardner & Moore (2004)	2 case studies (22-year-old intercollegiate male swimmer; 37-year-old female power-lifter)	Mindfulness-Acceptance-Commitment-Based Approach to Athletic Performance Enhancement (MAC approach); Adapted from MBCT and ACT	12 sessions; I. Decrease "experiential avoidance" II. Acceptance of thoughts, feelings, sensations, etc. III. Clarify values/commitment to behaviors IV. Heighten mindful awareness	AAQ PSWQ SAS	• Swimmer performed personal best; won two meets, two personal-best times • Swimmer's PSWQ score ↓ from 67 to 43 (post intervention) • Swimmer's AAQ score ↓ from 81 to 50

					• Power-lifter competed at highest competitive level in years, lifting 15% beyond previous performances • Power-lifter’s AAQ score ↓ from 77 to 43 • Power-lifter’s SAS (distraction subscale) ↓ from 27 to 12
		<u>Mindful Sport Performance Enhancement (MSPE)</u>			
De Petrillo, et al. (2009)	25 recreational long-distance runners (15 females, 10 males; M_{age} = 34.73 yrs, range = 18-55)	MSPE; 2 conditions: MSPE (n = 13), wait-list control (n = 12)	Designed to promote “flow” See below (Kaufman, Glass, & Arnkoff, 2009)	SAS TMS	• Mindfulness (decentering subscale; post-MSPE) > Mindfulness (decentering; pre-MSPE), F (1, 7) = 7.11* • Mean weekly running frequency increased, pre- to post-intervention, t = 3.01* • Sport related worry ↓ pre- to post-MSPE in

					both conditions, $t = 2.35$*
Kaufman, Glass, & Arnkoff (2009)	32 recreational athletes (23 males, 9 females, M_{age} = 52.19 yrs)	Mindful Sport Performance Enhancement (MSPE); Adapted from MBCT and MBSR	4, 2.5-3 hour sessions; Mindfulness exercises: I. raisin exercise; II. Body scan; III. Mindful breathing; IV. Sitting meditation; V. mindful yoga; VI. Walking meditation adapted to sport	KIMS SAS TMS	• Satisfaction with sport performance ↑ pre- to post-, $t = 3.24$**
		<u>Exploratory</u>			
Bernier, et al. (2009) Experiment #1	10 elite swimmers (6 males, 4 females; M_{age} = 20.23, *SD*= 2.87)	None	None	45-60 min. interview on subjective experience of swimming	• optimal performance included: “total concentration”; “sense of total control”, heightened awareness of bodily sensations
Gooding & Gardner (2009)	17 male intercollegiate basketball players (≥ 18 yrs)	None	None	MAAS	• Game free-throw percentage and MAAS, $r = 0.13$*
		<u>Unmanualized Interventions</u>			
Solomon & Bumpus (1978)	50 participants (no demographics reported)	Running Meditation Response: An Adjunct to Psychotherapy	Running and transcendental meditation (mantra—“one”); I. “Eye-rolling” technique to foster “runner’s high” (altered state of consciousness before running) II. “Slow, long distance running” for 60 min, 3-5x/week	None	• Reportedly, eventually produces “runner’s high”, no statistics reported • Reportedly may reduce effort while running,

no
statistics
reported

Note. * *P*< .05, ** *p* < .01, *** *p* < .001

Acronym Key
AAQ = Acceptance and Action Questionnaire (Hayes, Strosahl, & Wilson, 1999)
KIMS= Kentucky Inventory of Mindfulness Skills (Baer, Smith, & Allen, 2004);
MAAS = Mindful Acceptance Awareness Scale (Brown & Ryan, 2003)
MMS = Mindfulness/Mindlessness Scale (Bodner & Langer, 2001);
OMSAT-3 = Ottawa Mental Skills Assessment Tool-3 (Durand-Bush, Salmela, & Green-Demers, 2001)
PSWQ = Penn State Worry Questionnaire (Meyer, Miller, Metzger, & Borkovec, 1990)
SAS = Sport Anxiety Scale (Smith, Smoll, & Schutz, 1990)
TMS = Toronto Mindfulness Scale (Lau, et al., 2006)
TOPS = Test of Performance Strategies (Thomas, Murphy & Hardy, 1999)

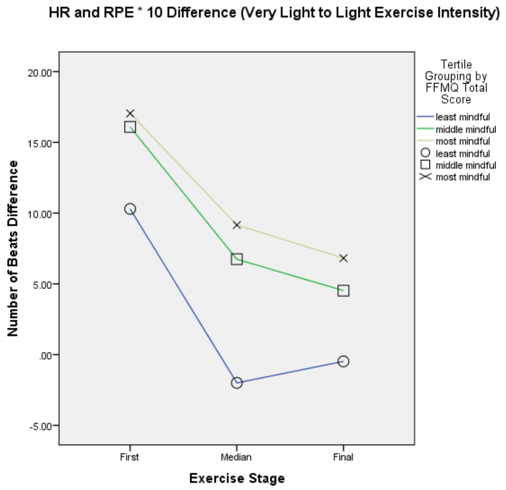
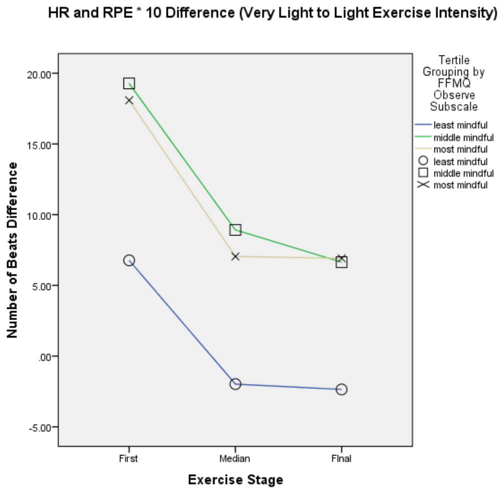


Figure 3. Mixed-design ANOVA of RPE accuracy with FFMQ Total score during very light to light exercise intensity

Table 22

Means and Standard Deviations of RPE accuracy among Mindfulness Tertiles (FFMQ Total Score) during Very Light to Light Intensity

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 10.30 *SD* = 15.24 *n* = 27	*M* = -2.0 *SD* = 17.89 *n* = 27	*M* = -.48 *SD* = 19.32 *n* = 27
Middle Mindful	*M* = 16.09 *SD* = 16.47 *n* = 27	*M* = 6.74 *SD* = 16.69 *n* = 27	*M* = 4.52 *SD* = 16.88 *n* = 27
Most Mindful	*M* = 17.05 *SD* = 16.00 *n* = 22	*M* = 9.16 *SD* = 18.98 *n* = 22	*M* = 6.82 *SD* = 20.32 *n* = 22



<u>Figure 4.</u> Mixed-design ANOVA of RPE accuracy during very light to light intensity, with FFMQ Observe subscale scores as the between subjects factor.

Table 23

<u>Means and Standard Deviations of RPE Accuracy among FFMQ Observe Subscale Scores during Very Light to Light Exercise Intensity)</u>

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 6.77 *SD* = 15.93 *n* = 28	*M* = -1.98 *SD* = 16.99 *n* = 28	*M* = -2.36 *SD* = 17.34 *n* = 28
Middle Mindful	*M* = 19.28 *SD* = 13.74 *n* = 25	*M* = 8.92 *SD* = 19.60 *n* = 25	*M* = 6.64 *SD* = 20.93 *n* = 25
Most Mindful	*M* = 18.09 *SD* = 15.41 *n* = 23	*M* = 7.04 *SD* = 16.60 *n* = 22	*M* = 6.91 *SD* = 17.02 *n* = 23

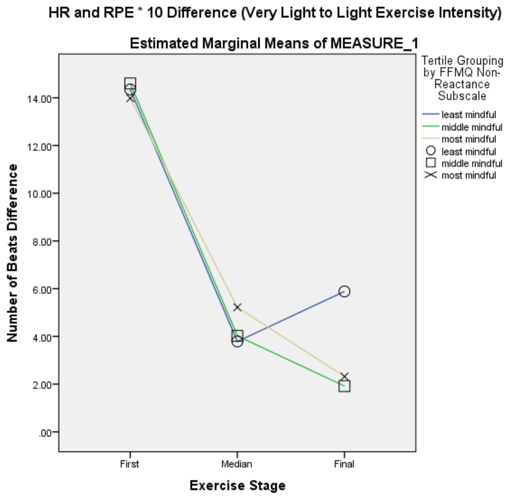


Figure 5. Mixed-design ANOVA of RPE accuracy during very light to light exercise intensity, with FFMQ Non-Reactance subscale scores as the between subjects factor.

Table 24

Means and standard deviations of RPE accuracy among mindfulness tertiles (FFMQ Non-Reactance Subscale)

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 14.35 *SD* = 14.34 *n* = 26	*M* = 3.79 *SD* = 18.59 *n* = 26	*M* = 5.88 *SD* = 21.28 *n* = 26
Middle Mindful	*M* = 14.60 *SD* = 19.91 *n* = 25	*M* = 4.02 *SD* = 18.03 *n* = 25	*M* = 1.92 *SD* = 17.21 *n* = 25
Most Mindful	*M* = 13.98 *SD* = 13.68 *n* = 25	*M* = 5.22 *SD* = 18.72 *n* = 25	*M* = 2.32 *SD* = 18.03 *n* = 25

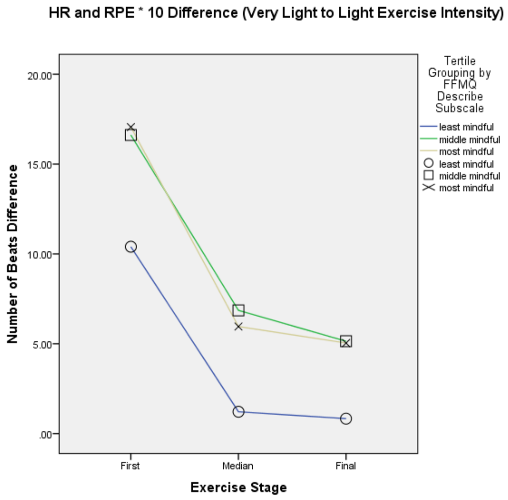


Figure 6. Mixed-design ANOVA of RPE accuracy during very light to light exercise intensity with FFMQ Describe Subscale scores as the between subjects factor.

Table 25

Means and Standard Deviations of RPE accuracy Among FFMQ Describe Subscale Tertiles (Very Light to Light Exercise Intensity)

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 10.40 *SD* = 17.52 *n* = 30	*M* = 1.22 *SD* = 16.59 *n* = 30	*M* = .83 *SD* = 17.33 *n* = 30
Middle Mindful	*M* = 16.62 *SD* = 10.43 *n* = 21	*M* = 6.86 *SD* = 20.76 *n* = 21	*M* = 5.14 *SD* = 20.65 *n* = 21
Most Mindful	*M* = 17.06 *SD* = 17.45 *n* = 25	*M* = 5.96 *SD* = 18.02 *n* = 25	*M* = 5.04 *SD* = 19.27 *n* = 25

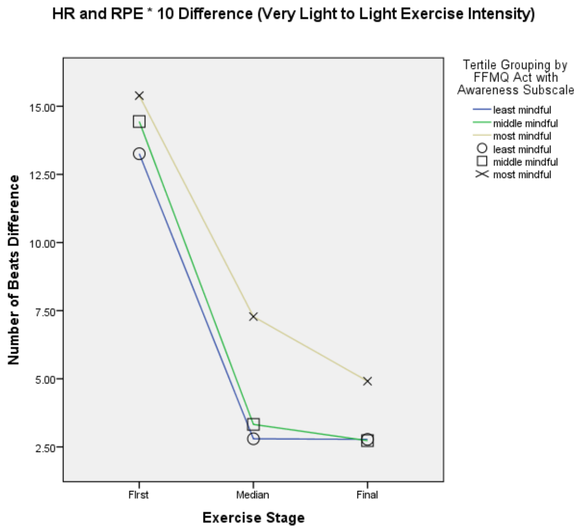


Figure 7. Mixed-design ANOVA of RPE accuracy during very light to light exercise intensity, with FFMQ Act with Awareness subscale scores as the between subjects factor.

Table 26

Means and Standard Deviations of RPE accuracy Among FFMQ Act with Awareness Subscale Tertiles (Very Light to Light Exercise Intensity)

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 13.26 *SD* = 17.16 *n* = 27	*M* = 2.80 *SD* = 20.12 *n* = 27	*M* = 2.78 *SD* = 21.34 *n* = 27
Middle Mindful	*M* = 14.44 *SD* = 16.17 *n* = 26	*M* = 3.33 *SD* = 15.80 *n* = 26	*M* = 2.73 *SD* = 17.93 *n* = 26
Most Mindful	*M* = 15.39 *SD* = 14.93 *n* = 23	*M* = 7.28 *SD* = 18.87 *n* = 23	*M* = 4.91 *SD* = 17.22 *n* = 23

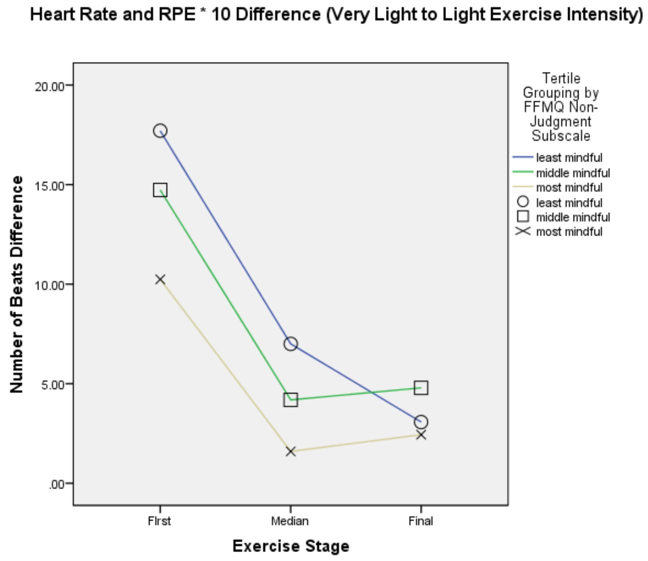


Figure 8. Mixed-design ANOVA of RPE accuracy during very light to light exercise intensity, with FFMQ Non-Judgment subscale scores as the between subjects factor.

Table 27

Means and Standard Deviations of RPE Accuracy among FFMQ Non-Judgment Subscale Tertiles (Very Light to Light Exercise Intensity)

Tertile	First Stage (HR – RPE * 10)	Median Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 17.70 *SD* = 10.98 *n* = 27	*M* = 7.00 *SD* = 19.44 *n* = 27	*M* = 3.07 *SD* = 18.85 *n* = 27
Middle Mindful	*M* = 14.73 *SD* = 18.14 *n* = 24	*M* = 4.19 *SD* = 15.58 *n* = 24	*M* = 4.79 *SD* = 17.91 *n* = 24
Most Mindful	*M* = 10.24 *SD* = 17.93 *n* = 25	*M* = 1.60 *SD* = 19.47 *n* = 25	*M* = 2.44 *SD* = 20.20 *n* = 25

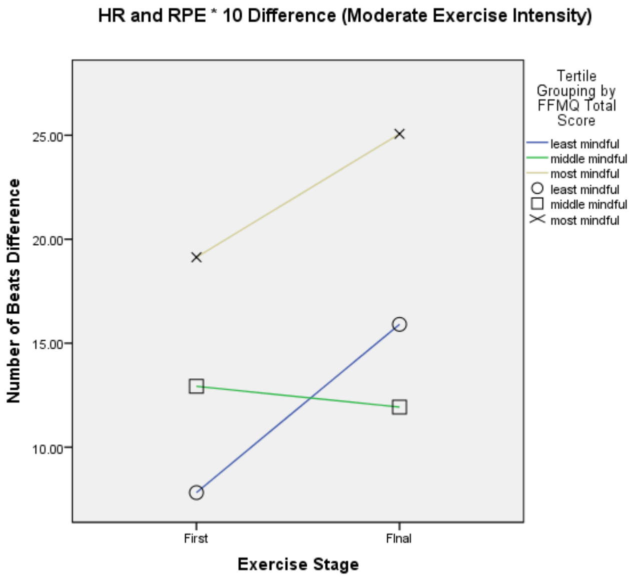


Figure 9. Mixed-design ANOVA of RPE accuracy during moderate exercise intensity, with FFMQ Total Score tertiles as the between subjects factor.

Table 28

Means and Standard Deviations of RPE accuracy Among FFMQ Total Score Tertiles (Moderate Exercise Intensity)

Tertile	First Stage (HR – RPE * 10)	Final Stage (HR – RPE * 10)
Least Mindful	*M* = 7.82 *SD* = 22.48 *n* = 11	*M* = 15.91 *SD* = 25.87 *n* = 11
Middle Mindful	*M* = 12.93 *SD* = 16.53 *n* = 14	*M* = 11.93 *SD* = 18.16 *n* = 14
Most Mindful	*M* = 19.13 *SD* = 24.53 *n* = 15	*M* = 25.07 *SD* = 24.88 *n* = 15

APPENDICES

Appendix 1

Treadmill Protocol

The current protocol was comprised of “active” stages designed to increase HR up to 76 %APHR_{Max}, followed by “cool down” stages to return to below 100 BPM. Active stages included 60-120 second stages of stable exercise intensity until intensity (indexed to individualized estimated % APHR_{Max}) gradually increased in a step-wise manner (2-10% increases in APHR_{Max}) at the end of each stage up to a pre-identified HR associated with moderate intensity exercise (approximately 76% of APHR_{Max}). The treadmill screen was covered by a sheet of opaque paper to ensure participants were unable to visually monitor exercise intensity increases. Self-reported ratings of perceived exertion, affect, and arousal were collected 60-seconds after each stage began and again 15 seconds prior to the end of each stage. Cool down stages ranged from 30 to 120 seconds and intensity decreased markedly and RPE and affect ratings were collected every 30-60 seconds. Participants were asked to respond to each scale by pointing to their response on 9” X 12” copies, which the research assistant confirmed by repeating the response aloud.

Testing was to be terminated with: 1) volitional fatigue; 2) onset of angina or angina-like symptoms; 3) shortness of breath, wheezing, leg cramps, or claudication (limping); 4) signs of poor perfusion: light headedness, confusion, gross lack of coordination of muscle movements, paleness, blue coloration of the skin, nausea, cold and clammy skin; 5) failure of HR to increase with increased exercise intensity; 6) noticeable change in heart rhythm; 7) physical or verbal manifestations of severe fatigue; 8) failure of the testing equipment. It is of note that testing needed to be temporarily stopped for approximately two to five minutes and restarted on three separate occasions due to equipment malfunction, particularly the HR monitor; data from those participants was included in analyses.

Initially, participants were instructed to step on the treadmill, at which time HR, RPE, and affect measures were collected. Incremental increases in exercise intensity occurred every 90-120 seconds, with standardized increases in speed (0.5 miles per hour [mph]) and elevation (0.2% grade) if % APHR_{Max} increased between 6% (+/- 4%) within the first 30-40 seconds of each stage. Based upon pilot testing, these increases were thought to induce 6% (+/- 4%) increases in APHR_{Max} in moderately to highly fit undergraduates age 18-23.

All participants began at a treadmill speed and elevation of 1.5 mph and 0.5% grade, respectively. At the beginning of the second stage, treadmill speed and elevation will increase to 2.5 mph and 0.7%, respectively. Thirty to forty seconds after the start of the second stage, if HR increases from the beginning of the stage between 6% (+/- 4 %) of % APHR_{Max}, intensity remained stable. However, if changes in % APHR_{Max} from the beginning of the stage were below 6% (+/- 4%), treadmill speed was increased by 0.2-0.4 mph and 0.1-0.3% grade at 30-second intervals until % APHR_{Max} increases by 6% (+/- 4%) from % APHR_{Max} at the beginning of the stage. If % APHR_{Max} increased beyond 6% (+/- 4%) 30-40 seconds after the beginning of the stage, speed was reduced by 0.2-0.4

mph and elevation by 0.1-0.2% grade until changes in % $APHR_{Max}$ decreased to 6% (+/- 4%) from the beginning of the stage. The two-minute stage restarted if the intensity was altered. This procedure was followed until participants transition from walking to jogging (typically around 3.5-4.5 mph), at which time HR increased by 16% (+/- 8%) of % $APHR_{Max}$. After this stage, intensity increases followed the same procedure (indexed to individualized changes in % $APHR_{Max}$) if HR range was between 6% (+/- 4% of $APHR_{Max}$). If HR is above this range, speed decreased by 0.1-0.4 mph and elevation decreased by 0.1-0.3% grade until desired HR range was achieved. This procedure was completed until 76% $APHR_{Max}$ was attained.

Once 76% $APHR_{Max}$ was attained, a series of "cool down" stages in which incremental decreases in treadmill speed and elevation occurred. Initially, treadmill speed decreased by 1.0-2.5 mph and 0.1-0.5% grade for one 30 second stage and then again by 0.5-1.5 mph and 0.1-0.5% grade every 30-60 seconds until HR was below 100 BPM. Similar to previous stages, changes in intensity were indexed to changes in % $APHR_{Max}$. Specifically, intensity was decreased to induce 20% (+/- 10%) decreases in % $APHR_{Max}$ by the end of each 30-60 second stage. If % $APHR_{Max}$ decreased by more than 20% (+/- 10%) (indicating HR was decreasing rapidly), speed decreased by 0.3-0.5 mph. If % $APHR_{Max}$ decreasd by less than 20% (+/- 10%) by the end of the second "cool down" stage, treadmill speed decreased by an additional 0.1-0.3 mph every 30-60 seconds until a change of 20% (+/- 10%) of % $APHR_{Max}$ from the beginning of the stage occurs. Similar to the active stages, the timing of each stage was restarted if time exercise intensity deviated from standardized decreases.

Appendix 2

Summary Results of All Hypotheses

Primary Hypotheses	FFMQ Subscale	Result (significance)
1	Total	Supported, in opposite direction**
	Observe	Partially supported, in opposite direction*
	Non-Reactance	Unsupported
	Describe	Supported, in opposite direction**
	Awareness	Supported, in opposite direction**
	Non-Judgment	Unsupported
2	Total	Partially supported*
	Observe	Unsupported
	Non-Reactance	Unsupported
	Describe	Partially supported*
	Awareness	Partially supported*
	Non-Judgment	Unsupported
3	Total	Unsupported
	Observe	Unsupported
	Non-Reactance	Unsupported
	Describe	Supported**
	Awareness	Unsupported
	Non-Judgment	Unsupported
4	Total	Unsupported
	Observe	Unsupported
	Non-Reactance	Unsupported
	Describe	Unsupported
	Awareness	Unsupported
	Non-Judgment	Unsupported
Secondary Hypotheses		
1	Total	Unsupported
2	Total	Unsupported
3	Total	Unsupported
	Observe	Supported, main effect mindfulness**
	Non-Reactance	Unsupported
	Describe	Unsupported
	Awareness	Unsupported
	Non-Judgment	Unsupported
4	Total	Supported, interaction effect**
	Observe	Unsupported
	Non-Reactance	Unsupported
	Describe	Unsupported
	Awareness	Unsupported
	Non-Judgment	Unsupported

Primary Hypotheses: Establishing a Relationship between Mindfulness and RPE

Hypothesis 1. Mindfulness scores are *positively* correlated with RPE.

Hypothesis 2. Mindfulness scores account for a significant proportion of the variance in RPE.

Hypothesis 3. Mindfulness scores account for a significant proportion of the variance in RPE during *very light to light* exercise intensity.

Hypothesis 4. Mindfulness accounts for a significant proportion of the variance in RPE during *moderate* exercise intensity.

Secondary Hypotheses: Determining the Relationship between Mindfulness and RPE Accuracy

Hypothesis 1. Mindfulness i*ncreases* RPE accuracy during *very light to light* exercise intensity *(35-45% APHR*$_{Max}$ *up to 63% APHR*$_{Max}$*).*

Hypothesis 2. Mindfulness i*ncreases* RPE accuracy during during *moderate exercise intensity (64-76% APHR*$_{\mathrm{Max)}}$ (208 – 0.7 X age; Tanaka, Monahan, & Seals, 2001).

Hypothesis 3. Participants higher in mindfulness will more accurately rate their exertion during very *light to light* exercise intensity *(35-45% APHR*$_{Max}$ *up to 63% APHR*$_{Max}$*)* (208 – 0.7 X age; Tanaka, et al., 2001), with less mindful participants likely *under-rating* their exertion.

Hypothesis 4. Participants higher in mindfulness will more accurately rate their exertion during *moderate* exercise intensity (64-76% APHR$_{\mathrm{Max}}$), (208 – 0.7 X age; Tanaka, et al., 2001), with less mindful participants likely *over-rating* their exertion.

Appendix 3

ANOVA Results for Secondary Hypothesis 1

FFMQ Total score as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .65, *F* (2, 72) = 19.27, *p* < .001, partial eta squared = .35. There was no statistically significant main effect for mindfulness scores, *F* (2, 72) = 2.06, *p* = .13, partial eta squared = .05, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. There was no significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .95, *F* (4, 144) = .88, *p* = .48, partial eta squared = .02. RPE are displayed in Figure 1 for each mindfulness tertile, with the least mindful group reflecting the smallest difference between HR and RPE multiplied by 10. Further, the group reporting the highest mindfulness scores reflects the largest difference between HR and RPE. Although there are no significant differences among the mindfulness groups, Table 22 and Figure 3 suggests that less mindful scores reflect that least mindful participants were more likely to over report exertion, with the most mindful participants under reporting exertion.

FFMQ Observe as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .64, *F* (2, 72) = 19.92, *p* < .001, partial eta squared = .36. There was a statistically significant main effect for mindfulness scores, *F* (2, 73) = 4.21, *p* = .02, partial eta squared = .10. There was no significant interaction between mindfulness scores and RPE accuracy over time, Wilks Lambda = .99, *F* (4, 144) = .24, *p* = .92, partial eta squared = .007. Table 23 summarizes the means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR. Figure 4 displays the differences in FFMQ tertiles.

FFMQ Non-Reactance as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .65, *F* (2, 72) = 19.68, *p* < .001, partial eta squared = .35. There was no statistically significant main effect for mindfulness scores, *F* (2, 73) = .04, *p* = .96, partial eta squared = .001, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. There was no significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .95, *F* (4, 144) = .86, *p* = .49, partial eta squared = .02. RPE are displayed in Figure 5 for each mindfulness tertile, with the least mindful group reflecting the little difference between tertiles until the final stage, when the least mindful tertile has the largest difference between HR and RPE multiplied by 10; however there are no significant differences among the mindfulness groups. Table 24 summarizes the means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR.

FFMQ Describe subscale scores as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .65, *F* (2, 72) = 19.50, *p* < .001, partial eta squared = .35. There was no statistically significant main effect for mindfulness scores, *F* (2, 73) = 1.04, *p* = .36, partial eta squared = .03, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. There was no significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .99, *F* (4, 144) = .11, *p* = .98, partial eta squared = .003. There RPE are displayed in Figure 6 for each mindfulness tertile, with the least mindful group reflecting the smallest difference between HR and RPE multiplied by 10. Table 25 summarizes the means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR.

FFMQ Act with Awareness subscale scores as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .65, *F* (2, 72) = 19.42, *p* < .001, partial eta squared = .35. There was no statistically significant main effect for mindfulness scores, *F* (2, 73) = .23, *p* = .79, partial eta squared = .006, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. There was no significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .98, *F* (4, 144) = .87, *p* = .87, partial eta squared = .009. RPE are displayed in Figure 7 for each mindfulness tertile, with the least mindful tertile reflecting the smallest difference between HR and RPE multiplied by 10 and the highest mindfulness tertile reflecting the largest difference. Table 26 summarizes the means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR.

FFMQ Non-Judgment subscale scores as between subjects factor

There was a statistically significant main effect for time, Wilks Lambda = .65, *F* (2, 72) = 19.63, *p* < .001, partial eta squared = .35. There was no statistically significant main effect for mindfulness scores, *F* (2, 73) = .55, *p* = .58, partial eta squared = .015, suggesting no significant differences among mindfulness tertiles with regard to RPE accuracy. RPE are displayed in Figure 8 for each mindfulness tertile, with the most mindful tertile reflecting the smallest difference between HR and RPE multiplied by 10. There was no significant interaction between mindfulness scores and RPE over time, Wilks Lambda = .95, *F* (4, 144) = .89, *p* = .47, partial eta squared = .02. Table 27 summarizes the means and SDs among the three mindfulness groups at each stage of exercise intensity, with RPE values multiplied by 10 and then subtracted from HR.

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