Does a brief mindfulness intervention counteract the detrimental effects of ego-depletion in basketball free throw under pressure?

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Does a brief Mindfulness Intervention Counteract the Detrimental Effects of Ego-depletion in Elite Basketball free throw under pressure?

Abstract

Research has shown that a brief mindfulness intervention may counteract the depleting effects of an emotion suppression task upon a subsequent psychological task that requires self-control. However, the effects of a brief mindfulness intervention on perceptual–motor tasks particularly in stressful situations have not yet been examined. The purpose of this study was to investigate whether a brief mindfulness intervention can counteract the detrimental effects of ego-depletion in basketball free throw performance under pressure. Seventy-two basketball players (mean age = 28.6 ± 4.0 yrs) were randomly assigned to one of the following 4 groups: depletion/mindfulness, no depletion/mindfulness, depletion/no mindfulness and control (no depletion/no mindfulness). The mindfulness intervention consisted of a 15-min breathe and body mindfulness audio exercise, while the control condition (no mindfulness) listened to an audio book. A modified Stroop color-word task was used to manipulate self–control and induce ego depletion. Participants performed 30 free throws before and after the experimental manipulations. Results showed that basketball players' free throw performance decreased after ego-depletion, but when ego-depletion was followed by the mindfulness intervention, free throw performance was maintained at a level similar to the control group. Our results indicate that a brief mindfulness intervention mitigates the effects of ego depletion in a basketball free-throw task.

Keywords: attention regulation, emotional control, relaxation training, self-regulation, sport performance, stress.

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Athletes do not always perform to their capabilities, in particular under stressful anxiety-inducing conditions, when their best performance is required (Oudejans, Kuijpers, Kooijman, & Bakker, 2011). When success or failure has important consequences for the athlete (e.g., psychological, social, and financial), critical periods within a competition may pose an increased emotional and cognitive burden, which may hamper performance (Nieuwenhuys & Oudejans, 2012). Indeed, evidence suggests that pressure-induced anxiety interferes with athletes' attention regulation processes leading to impaired performance (Englert & Bertrams, 2012; Oudejans et al., 2011). Therefore, athletes must be able to volitionally down-regulate their anxiety and control their attention (Englert & Bertrams, 2012; Wilson, Vine, & Wood, 2009); that is, exert self-control (Baumeister, Vohs, & Tice, 2007; Englert, 2016). Self-control brings athletes closer to their long-term goals or standards of performance by facilitating the execution of task relevant actions and desired behaviors (Baumeister et al., 2007; Englert, 2016). However, exerting self-control is not always an efficient process because it increases the chances of self-control failure in future efforts. This psychological cost is called ego-depletion (Baumeister et al., 2007).

Processes underlying ego depletion are explained by several models, such as the shifting priorities model, also known as the process model (Inzlicht & Schmeichel, 2013; Inzlicht & Schmeichel, 2016), cost/benefit computations (Kurzban, Duckworth, Kable, & Myers, 2013) and strength model of self-control (Baumeister & Vohs, 2018; Baumeister et al., 2007). The strength model of self-control is one of the most popular models, and it postulates that self-control relies on a limited-independent resource that is partially and temporarily depleted by any act of self-control (Baumeister et al., 2007; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Muraven & Baumeister, 2000). This model has received considerable empirical support in a sport context. For example, it has been shown that a non-sports related primary task that requires cognitive effort, in particular attentional control (e.g., Stroop color word test), leads to self-control failures in a secondary physical task with decreases in repeated maximum force production in hand grip (Bray, Ginis, & Woodgate, 2011), electromyography amplitude (Bray, Ginis, Hicks, & Woodgate, 2008), endurance and power output in indoor cycling performance (Englert & Wolff, 2015), basketball free-throw (Englert & Bertrams, 2012) and dart-throwing (McEwan, Ginis, &

Bray, 2013). Additionally, in a narrative review, Pageaux and Lepers (2018) confirmed the existence of decrements in sport-related motor tasks after self-control depletion or mental fatigue. Other theoretical models challenge the notion of limited self-control strength, and highlight the importance of identifying other mechanisms through which the actual processes of ego depletion impair performance. For example, according to motivational and attentional shifts theory, exerting self-control in a first task reduces success at self-control at a second task due to shifts in motivation and attention (Inzlicht & Schmeichel, 2016). However, in a recent empirical study, Baumeister and Vohs (2018) argued that these alternative explanations of ego depletion suggested by other theoretical models, are aligned with the strength model of self-control. Regarding motivational and attentional shifts theory, Baumeister and Vohs (2018) suggested that limited resource theory works better if it is assumed that performance changes caused by ego depletion could be either a direct effect of low energy or an indirect effect mediated by motivational and attentional changes. By analogy, the effects of physical tiredness can be either direct or mediated by motivational and attentional shifts. In short, not only are energy depletion and motivational change compatible, but both gain plausibility when integrated together. Overall, while the discussion about underlying processes is ongoing, there is little doubt that self-control demands for initial tasks disrupt self-control for subsequent tasks (Hagger et al., 2010). Hence, in the current study, we emphasize the strength model of self-control to explain the ego-depletion effects.

Considering the importance of sustaining high performance levels, it is of interest to identify suitable training procedures for athletes to adequately regulate self-control and avoid ego depletion. Among the different procedures, mindfulness is a promising one. Derived from the Buddhist contemplative tradition, mindfulness refers to a heightened act in which meditators consciously and intentionally attempt to bring their full attention and awareness to the present moment with a non-judgmental attitude (Kabat-Zinn & Hanh, 2009). A growing body of evidence suggests that there is an association between self-control and mindfulness (Bowlin & Baer, 2012; Yusainy & Lawrence, 2014) and that the benefits of mindfulness are often conceptualized in terms of self-control (Bowlin & Baer, 2012). Attention and awareness, which are core elements of mindfulness, are crucial for detecting discrepancies between goals and progress (Bowlin & Baer, 2012; Yusainy & Lawrence, 2014) and for regulating thoughts, emotions, and actions to behave in agreement with goals, requirements, rules, or standards, even under stressful and anxiety-inducing conditions (Arch & Craske, 2006). Also the suppression or inhibition of unwanted responses have been found to be involved in both mindfulness and self-control (Audiffren & André, 2015).Thus, it seems that the mindfulness approach and self-control share some common mechanisms.

Concerning the use of mindfulness in the context of sport, one study reported that a brief period of mindfulness did not improve performance on a subsequent self-control task consisting of an endurance plank exercise (Stocker, Englert, & Seiler, 2018). However, another study reported that mindfulness improved performance in a handgrip perseverance exercise (Yusainy & Lawrence, 2015), but this effect was independent of a depletion condition. In contrast, Friese, Messner, and Schaffner (2012) have shown that a brief period of mindfulness practice mitigates the ego-depletion effect on a subsequent test of attention. Such conflicting findings across studies may be explained by the participants' different levels of experience with mindfulness. Furthermore, the tasks proposed in the aforementioned studies were different. While the sports studies required participants to engage in endurance exercises that caused fatigue and pain requiring participants to exert self-control to overcome the need to relax, Friese et al. (2012) used an attention task that required participants to exert self-control to overcome irrelevant and distracting stimuli. In addition, longer doses of mindfulness training may be required to mitigate ego depletion effects on the physical tasks compared to psychological tasks, potentially through an improved capacity to generate and sustain mindful states (Garland, Hanley, Farb, & Froeliger, 2015). Overall, studies in sport have focused mainly on endurance tasks; hence, it is still unknown whether the results will be replicated for perceptual-motor tasks such as basketball free throws.

In perceptual-motor tasks, self-control strength may be beneficial in preventing performance impairments caused by stress, anxiety, and potentially distracting stimuli such as ruminative thoughts or crowd noise (Englert, Bertrams, Furley, & Oudejans, 2015; Wilson et al., 2009). Under stressful conditions, athletes may worry about their performance, which takes up cognitive resources and may lead to choking (Oudejans et al., 2011). High pressure environments are often associated with decreased performance due to overloading of working memory as a result of excessive ruminative thoughts (Beilock & Carr, 2005), worries or task-irrelevant stimuli (Masters & Maxwell, 2008). To avoid performance decrements, athletes attempt to consciously control aspects of performance by applying explicit and rule-based knowledge to movement execution, a process named reinvestment (Masters & Maxwell, 2008). Hence, reinvestment results in attentional shifts to internal and narrow cues with the consequent overload of athletes' cognitive resources (Masters & Maxwell, 2008). This overload might be reduced through mindfulness training. The probability of mindful individuals being affected by these distracting stimuli may be lower, as they tend to accept them as part of the here-and-now experience, instead of actively trying to suppress them (Birrer, Röthlin, & Morgan, 2012). In addition, with mindfulness, athletes learn to adopt a non-judgemental and non-reactive attitude towards performance, based on self-respect whether performance is excellent or unexpectedly poor. In this way, the constant rumination over the distracting thoughts and additional emotional and cognitive workload may be prevented (Birrer et al., 2012), resulting in a positive impact on the performance of perceptual motor tasks.

The aim of the present study was to examine whether a brief mindfulness intervention can counteract the detrimental effects of ego-depletion in basketball free throw under pressure. Participants were randomly assigned to one of following 4 groups: depletion/mindfulness, no depletion/mindfulness, depletion/no mindfulness and control (no depletion/no mindfulness).We hypothesized that, compared to the control condition, participants' shooting scores between pre and post tests would: 1) decrease in the depletion condition ; 2) increase in the mindfulness condition ; 3) not change in the depletion-mindfulness condition . Furthermore, we analysed the mediation effect of state mindfulness in the relationship between the intervention and the basketball shooting score. We hypothesize that state mindfulness is a mechanism through which the mindfulness intervention can affect basketball shooting score.

Methods

Participants

A total of 72 experienced male basketball players (Age: 28.6 ± 4.0 yr; min = 20; max = 35; Height: 193.0 ± 7.5 cm; BMI: 20.6 ± 2.0), were recruited via flyers and posters from second and third tier competitive leagues throughout a large urban environment in (Blind). Recruitment took place between December 2017 and March 2018. Inclusion criteria included: 1) no prior experience with mindfulness; 2) participation in at least 85% of basketball training sessions in the current season and regular participation in competitions in the previous season; 3) absence of pain or prior physical injuries; 4) currently not taking any medication.

Study design

A 2x2x2 between-within ANCOVA design was used to test our hypotheses. Ego-depletion condition (depletion vs. no depletion), and intervention (mindfulness vs. no mindfulness) were the between factors, while time (pre-test vs. post-test) was the within factor. Trait mindfulness, trait anxiety, trait self-control, and depletion sensitivity were used as covariates.

Measures

Control Measures

Sport Anxiety Scale-2 (SAS-2; Smith, Smoll, Cumming & Grossbard, 2006). As trait anxiety can affect action initiation and selective attention (Englert & Bertrams, 2012), participants' trait anxiety was used as a covariate. SAS-2 consists of 21-items that measure three subscales comprised of four items each: Worry (e.g., "*I worry that I will not play well*"), somatic anxiety (e.g., "*My body feels tense*"), and concentration disruption (e.g., "*It is hard to concentrate*"). Participants were asked to indicate on a 4-point Likert-type scale ranging from 1 (*not at all*) to 4 (*very much*) how they generally feel before or during sporting competitions. The internal consistency of this scale was adequate (Cronbach-α = .86). The construct validity of SAS-2 has been supported by strong correlations with self-esteem (r= .90)(Smith et al., 2006).

Daily Inventory of Stressful Events (DISE; Brantley, Waggoner, Jones & Rappaport, 1987). This inventory includes a list of possible daily stressors, and participants indicated by circling either 'yes' or 'no' the stressful events they had experienced in the last 24 hours (e.g., "*An argument or disagreement with someone*"). DISE has shown concurrent validity through high correlation with global rating of stress (r = .72). Test-retest reliability (ICC = .82) of daily stressors has also previously been reported (Brantley et al., 1987).

Depletion Sensitivity Scale (DSS; Salmon, Adriaanse, De Vet, Fennis & De Ridder, 2014). This is an 11-item scale which was used to measure individual differences in ego-depletion sensitivity. Participants were asked to indicate on a 7-point Likert-type scaleranging from 1 (*totally disagree*) to 7 (*totally agree*) the extent to which each item applies to them (e.g., "*After I have worked very hard at* *something, I am not good at reloading to start a new task*"). A total sum is calculated and high scores indicate higher depletion sensitivity (Cronbach's alpha =.88). The construct validity of DSS is supported by correlations with trait self-control scale (r =.62) (Salmon et al., 2014).

Positive and Negative Affect Schedule (PANAS; Thompson, 2007). This inventory measures two affective states: negative mood (e.g., sad) and positive mood (e.g., happy). A score for each scale is calculated by the sum of the responses to10items. . Participants answered the question "*how do you feel right now?*" on a five-point Likert-type scale, ranging from 1 (*not at all*) to 5 (*very much*) (Cronbach's alpha .78 and .79; respectively). The convergent validity of both the PA and NA subscales were verified by moderate correlations with happiness (r =.39 and r = -51; respectively) and test-retest reliability for both the PA and NA subscales (ICC= .84) have been reported by Thompson(2007).

Comprehensive Inventory of Mindfulness Experiences (CHIME; Bergomi, Tschacher, & Kupper, 2014). Trait mindfulness was also measured to be used as a covariate because it can affect ego-depletion and sport performance (Birrer et al., 2012) as well as interact with ego-depletion (Imhoff, Schmidt, & Gerstenberg, 2014; Salmon et al., 2014). The CHIME is a 37-item inventory that describes a variety of scenarios participants may have experienced during the previous two weeks. Participants were asked to rank their mindful engagement with each of those scenarios (e.g., "*When my mood changed, I noticed that immediately*"), on a six-point Likert scale from 1 (*almost never*) to 6 (*almost always*) (Cronbach's alpha =.79). Bergomi et al. (2014) provided support for convergent validity of CHIME though moderate correlation with art-of-living (r =.48).

Brief Self-Control Scale (BSCS; Tangney, 2018). Trait self-control was also used as a covariate due to its relationships with ego-depletion and sport performance (Birrer et al., 2012; Imhoff et al., 2014; Salmon et al., 2014). The BSCS is a 13-item instrument that requires participants to indicate on a 5-point Likert scale, ranging from 1 (*not at all*) to 5 (*very much*), to what extent each item applies to them (e.g., "*I refuse things that are bad for me*") (Cronbach's alpha =.81). The construct validity of BSCS is supported by strong correlations with self-esteem score (r = .72). Moreover, test-retest reliability (ICC = .87) has been reported previously (Tangney, 2018).

Manipulation and intervention check measures

Ego-depletion manipulation check (EDMC; Englert & Wolff, 2015; Stocker et al., 2018). Participants completed a four-item manipulation check ("*How difficult did you find the task?*'', "*How effortful did you find the task?*", "*How mentally depleted do you feel at the moment?*", and ''*When reporting the color of the words, how difficult was it to suppress the meaning of the words?*''). This procedure was adapted from previous research to ascertain the efficacy of the self-control manipulation task (Englert & Wolff, 2015; Stocker et al., 2018).This measure assessed whether participants in the depletion condition actually exerted more self-control than participants in the non-depletion condition. Items were answered on a 7-point Likert-type scale from 1 (*not at all*) to 7 (*very much*). The internal consistency of this scale was acceptable (Cronbach's alpha =.84).

Toronto Mindfulness Scale (TMS; Lau et al., 2006). The TMS captures the extent to which respondents experienced a feeling of heightened awareness, as well as the quality of such awareness. TMS was used to examine the efficacy of the mindfulness intervention, reflected by changes in mindfulness states. It includes 13 items that measure two state mindfulness factors: openness and curiosity (curiosity factor) and the ability to be aware of one's thoughts and feelings without becoming entangled in them (decentering factor). Answers are provided on a five-point Likert scale, ranging from 0 (*not at all*) to 4 (*very much*). Higher total scores indicate higher overall state mindfulness. In the current study, this scale showed acceptable internal consistency (Cronbach's alpha = .82). Lau et al. (2006) provided support for convergent validity of both the curiosity and decentering subscales though moderate correlation with absorption (r =.31 and r = 22; respectively).

Outcome measure

Basketball shooting score. Participants performed 30 free-throws in a pressure situation after approximately 5 to 10 min of individual warm-up and 10 practice free throws. Participants' shooting score was calculated as the percentage of successful free-throws [number of successful shooting/30)*100], both at pre-test and post-test.

Experimental manipulation

Ego-depletion

The modified Stroop color-word task was used to experimentally manipulate ego-depletion. This task has been used to deplete self-control strength in many self-regulation studies (Englert & Wolff, 2015; McEwan et al., 2013; Muraven & Baumeister, 2000). The task included six colored words (BLACK, BLUE, GREEN, RED, PINK, and GRAY) randomly presented on a white background in 48-size Times New Roman font on a 17-inch flat-screen computer monitor. Here, only incongruent trials, in which word and color differ (e.g., the word BLUE is printed in red), were used. Participants were required to verbalize as quickly and accurately as possible the ink color of the words while ignoring the word content. The task was set up so that participants performed five 3-min blocks each, consisting of 135 trials, separated by four 30-s breaks. Trials were visible on the monitor for one second followed by a 100-ms inter-trial interval in which the screen was white.

Sham self-control

Amodified Stroop color-word task that included congruent trials was used, where the word content matched the print color (e.g., the word 'BLUE" is printed in blue, 'RED' is printed in red). Therefore, verbally communicating the color of the ink in this congruent task is not cognitively challenging and does not require self-control (Baumeister et al., 2007).

Mindfulness training

The aim of the mindfulness intervention was to direct participants' attention and awareness to whatever sensations they were experiencing, with a particular focus on the experience of breathing. Moreover, participants were instructed to gently return their thoughts to the present moment each time a distracting thought, emotion or memory occurred or when they drifted towards irrelevant information. Mindfulness with regards to the body and breathing was used because it can be successfully sustained for extended periods by novice participants without creating stress (Yusainy & Lawrence, 2015). This exercise has been widely used in Mindfulness stress reduction (Kabat-Zinn & Hanh, 2009) and Mindfulness based cognitive therapy (Segal, Williams, & Teasdale, 2002) programs in previous studies (Arch & Craske, 2006; Friese et al., 2012; Yusainy & Lawrence, 2015).

The mindfulness intervention consisted of a 15-min audio for: 1) ''*focused breathing induction*'', where the participants focused on their breathing; 2) "*breathing and body mindfulness*", which incorporated focusing on both breathing patterns and physical body sensations. They were also told that: "*In this practice, there is no need to think about breathing—just experience the sensations of it. When you notice that your awareness is no longer on breathing, gently bring your awareness back to the* *sensations of breathing*." Participants in the mindfulness groups (i.e., mindfulness and depletion-mindfulness groups) attended two sessions of 15 min of mindfulness training in two groups of 18 participants, two days prior to the start of the study. Participants in the depletion and control groups listened to a 15-min audiobook segment about natural history of (blind). A Ph.D. student of clinical psychology, who had expertise in sport psychology, was blind to the purpose of the experiment and was not a member of the research team, delivered the program.

Sham mindfulness intervention

A 15-min audio recording of a natural history text of (blind), which was deemed unlikely to elicit emotions, was used as an active control condition of the mindfulness intervention. A similar procedure has been used elsewhere (Stocker et al., 2018; Yusainy & Lawrence, 2015).

Procedures

All procedures were approved by the Institution's Review Board of (Blinded) and were in accordance with the Declaration of Helsinki. All clinical assessments were performed at a training facility of a community-based basketball club (Blind), where participants were invited to attend individually. Assessments were conducted by the same researcher. First, participants were presented with a brief description of the experiment and signed a written informed consent. They then completed the following six questionnaires: demographic information (i.e., age, BM, height, and years of basketball experience), sport anxiety scale-2, comprehensive inventory of mindfulness experiences, brief self-control scale, depletion sensitivity scale, and Toronto mindfulness scale before the completed 30 experimental free throws. Next, participants completed 30 experimental free throws from the free throw line with an official game ball. The score on these throws served as baseline (pre-test) performance data. The free throw line was located 4.60 m from the basket, which was placed at a height of 3.04 m from the ground. Free throws were performed under a generated pressure situation. Pressure was induced by informing participants that their individual and team performance would be ranked and made public among participants. During the free-throw task, all participants listened to distracting audio messages, which included 17 sentences with a total of 137 words and 54 seconds duration. The audio messages were delivered via stereo headphones in two different monotonous digital voices (a female and a male voice) during the entire shooting task (longest time needed to complete the task was 5.22 min). The audio messages were typical worrisome thoughts athletes tend to experience in high pressure situations (e.g., "*I was worrying about my performance*") and were adapted from Oudejans et al. (2011) and applied in previous studies (Englert & Bertrams, 2016; Englert et al., 2015). Participants were requested to focus just on the free throws and ignore the audio stream.

Following the baseline measurements (pre-test), participants were randomly assigned to one of four conditions: depletion only (depletion group), depletion-mindfulness (depletion-mindfulness group), mindfulness only (mindfulness group) and control (control group), and proceeded to perform the experimental activities described above depending on the assigned treatment conditions. The latter group performed the sham self-control and the sham mindfulness procedures. Participants in the depletion and depletion-mindfulness groups performed the modified Stroop color-word task (SC-WT) to manipulate their self-control strength (ego-depletion), whereas participants in the mindfulness and control groups performed the non-self-control condition. Participants then completed the positive and negative affect schedule (Thompson, 2007), to check for possible unintended effects of the modified Stroop color-word task on mood. This procedure was deemed necessary as it has been shown that overriding a well-learned behavior may negatively impact emotional states (McEwan et al., 2013; Stocker et al., 2018). Finally, participants completed the four-item ego-depletion manipulation check to determine the effectiveness of the self-control manipulation task. In the next phase, the mindfulness and depletion-mindfulness groups listened to 15-min audio mindfulness training and the depletion and control groups listened to a story about the natural history of Iran. Immediately after the mindfulness induction or audiobook listening, the Toronto mindfulness scale (Lau et al., 2006) was used as a manipulation check measure to assess participants' current state of mindfulness. Finally, participants completed the 30 free-throws post-test performance task, in similar conditions to the pre-test. The ego-depletion induction and mindfulness intervention took place between two sets of basketball free throws. The first set of free throws (pre-test) took place before the ego-depletion induction and mindfulness intervention and the second set of free throws (post-test) took place after the manipulation of self-control strength and mindfulness intervention. Throughout the experiment, participants of both groups performed the tasks under the same environmental conditions. At the end of the experiment, participants were debriefed. Figure 1 represents a flow chart depicting the study procedure.

(Insert Figure 1 about here)

Data Analyses

SPSS statistical software (Version 18.0, SPSS Inc., Chicago, IL) was used for all statistical analyses. Threshold for statistical significance was set at $p < .05$ and values are presented as mean ± SD with 95% confidence intervals (CIs). The Shapiro–Wilk test was used to assess normality of all variables. One way ANOVAs were used to compare sport anxiety, depletion sensitivity, affective states and ego-manipulation scores between groups at baseline. A 2 (Depletion vs. No depletion) x 2 (mindfulness vs. No mindfulness) x 2 (pre-test vs. post-test) ANCOVA was used to test the main and interaction effects of ego-depletion and mindfulness for the TMS and basketball free throw. Trait mindfulness, trait anxiety, trait self-control, and depletion sensitivity were used as covariates. Additional follow-up comparisons were conducted using Tukey's tests for multiple comparisons.

A Pearson correlation was used to evaluate whether changes of basketball shooting scores were associated with participants' TMS score change. This analysis was then repeated for the decentering and curiosity subscale scores of TMS separately. Using model 4 of the macro PROCESS for SPSS (Hayes, 2013), a mediation analysis was conducted to determine whether mindfulness training had an indirect effect on changes in basketball free throw scores through state mindfulness. In this path model, experimental conditions (groups) were entered as the independent variable, changes of state mindfulness was entered as the mediator variable, and changes of basketball shooting scores was entered as the dependent variable. We used a bias corrected bootstrap test with 5000 bootstrap samples to determine the significance of indirect effects (Preacher & Hayes, 2008).

Partial eta squared (ηp^2) values of .01 to .059, .06 to .139, and ≥.14 represented small, moderate, and large effects, respectively (Cohen, 1973). To obtain a better understanding of the range of training gains, Cohen's d_z - expressing the effect size of the comparisons - was calculated with values of ≤ .19, .2-.49, .50-.80, and ≥ .81 representing trivial, small, medium, and large effects, respectively. Software package G*Power3.1 was used to calculate the sample size (Faul, Erdfelder, Buchner, & Lang, 2009). Based on effect size d = .52 (f = .26) of a previous study (Friese et al., 2012), we anticipated that for a 2-tailed significance level (α) of .05 and a desired power (1-β) of .90, a sample size of 15 in each group was needed. With an expected drop-out rate of 20%, we enrolled 18 participants in each group. We used F-test, repeated measures within-between interaction with 2 measurements and a correlation among repeated measures of .5.

Results

Table 1 represents the descriptive statistics for the participants' demographic information and control measures. There were no significant differences in age, height, BMI, years of sport participation, number of practice sessions per week and dominant arm between groups.

One-way ANOVAs were conducted to compare sport anxiety, depletion sensitivity, and affective states scores between groups at the beginning of the study. There were no significant differences in subscales of worry, $F(3,68) = 0.62$, $p = .58$, somatic, $F(3,68) = 0.43$, $p =.73$, and concentration, $F(3,68) = 0.24$, $p = .87$, of sport anxiety, and depletion sensitivity, $F(3,68) = 0.54$, $p = .66$ scores, indicating that participants of different groups had similar trait sport anxiety and susceptibility to ego deletion at the beginning of the study. In addition, there were no significant differences between groups in participants' positive affective states, $F(3, 68) = 0.56$, $p = .60$, and negative affective states, $F(3,68) = 0.46$, $p = .70$) indicating no unintended effects of the modified Stroop color-word task on mood (Table 1).

(Insert Table 1 about here)

After ego-depletion, there was a significant difference between groups in the score of the ego-manipulation check, $F (3, 68) = 51.9$, $p < .001$. Tukey's post hoc revealed that ego-manipulation scores for depletion and depletion-mindfulness groups were higher than the scores for control and mindfulness groups ($p< .001$). Specifically, participants subjected to the depletion manipulation (i.e., depletion and depletion-mindfulness groups) exerted more self-control than participants who were not subjected to depletion (i.e., control and mindfulness groups) indicating that the self-control manipulation task was effective (Figure 2).

(Insert Figure 2 about here)

For the TMS (used as a manipulation check measure to assess participants' mindfulness state change after the mindfulness intervention), the analysis of covariance revealed a significant main effect for mindfulness training, $F(1,64) =36.05$; $p = .001$; $n_p^2= 0.36$, and depletion condition, $F(1,64) = 7.71$; p

= .008; $n_p^2 = 0.11$, but not for time, $F(1,64) = 3.36$; $p = .08$; $n_p^2 = 0.05$. The time × depletion interaction was significant, $F(1, 64) = 9.98$; $p = .002$; $n_p^2 = 0.13$, indicating changes of state mindfulness after ego-depletion. The time × mindfulness interaction was significant, $F(1, 64) = 73.34$; $p = .001$; $n_p^2 = 0.53$, indicating a higher state mindfulness after the brief mindfulness training for those who participated in the mindfulness compared to those who did not. The effects of depletion × mindfulness, $F(1, 64) = .17$; $p = .68$; $n_p^2 = 0.003$, was not significant, indicating that the effects of the mindfulness intervention on state mindfulness of depleted and non-depleted participants were similar. Finally, time × depletion × mindfulness interaction effect was not significant, $F(1, 64) = 4.13$; $p = .06$; $n_p^2 = 0.06$, indicating that the effects of the brief mindfulness training on the participants' state mindfulness from pre- test to post–test were independent of depletion conditions (i.e., independent of whether or not participants are depleted). In other words, the effects of mindfulness training on state mindfulness from pre to post-test did not change due to the induction of ego-depletion (Table 2). Interaction effects are illustrated in Figure 3.

Tukey's post-hoc tests found that , after mindfulness training, state mindfulness improved significantly more in the mindfulness-depletion group compared to the depletion ($p < .001$) and control ($p <.001$) groups, indicating that brief mindfulness training may help improve state mindfulness in depleted participants. In addition, state mindfulness was significantly higher in the mindfulness group compared to the depletion ($p < .001$) and control ($p <.001$) groups, indicating that brief mindfulness training may also improve state mindfulness in non-depleted participants. Finally, post-hoc results show that state mindfulness was significantly lower in participants in the depletion group than in the control group ($p<.001$), indicating that ego-depletion may decrease state mindfulness (Fig 2c).

(Insert Table 2 about here)

Regarding free throw performance, results revealed a significant main effect for mindfulness, $F (1, 64) = 4.40$; $p = .04$; $n_p^2 = 0.06$, but not for time, $F (1, 64) =0.01$; $p = .84$; $n_p^2 = 0.001$, or depletion, $F (1, 64) = 1.57$; $p = .21$; $n_p^2 = 0.02$ (Table 2). The time × depletion interaction was significant, $F (1, 64) = 31.10$; $p = .001$; $n_p^2 = 0.32$, indicating a lower successful free throw shooting score after ego-depletion. The time × mindfulness interaction was also significant, $F(1, 64) = 27.05$; $p = .001$; $n_p^2 = 0.29$, indicating better free throw performance after mindfulness intervention for those who participated in the mindfulness training compared to those who did not. The effects of depletion × mindfulness, $F (1, 64) =$

0.45; $p = .50$; $n_p^2 = 0.01$, was not significant, indicating that the effects of mindfulness on performance of depleted and non-depleted participants were similar. Finally, a significant time × depletion × mindfulness interaction effect was also found, $F(1, 64) = 4.79$; $p = .05$; $n_p^2 = 0.06$. Post-hoc tests indicated that the effects of the brief mindfulness intervention on participants' shooting score improved more in non-depleted participants than in depleted participants. In other words, the effects of brief mindfulness on the basketball free throw performance from pre- to post-test may be weaker in depletion group due to ego-depletion (Table 2). Interaction effects are illustrated in Figure 3.

After mindfulness training, post hoc tests revealed that basketball free throw scores improved significantly in the mindfulness-depletion group compared to the depletion group ($p = .02$ – Fig. 2b). There were no statistically significant differences between the mindfulness-depletion group and the control group ($p > .05$), indicating that after mindfulness training free throw performance of mindfulness-depletion group participants improved close to the score of the control group participants. In addition, basketball free throw scores were significantly better in the mindfulness group compared to the depletion ($p < .001$), control ($p = .03$), and mindfulness-depletion groups ($p = .04$). Furthermore, free throw performance for participants of the depletion group was significantly lower than that of the control group ($p = .02$), indicating that ego-depletion may cause a decrease of basketball free throw (Fig 2b).

(Insert Figure 3 about here)

Finally, Person product-moment correlations showed significant associations between participants' free throw score change (from pre-to post-test),change of state mindfulness (r = .54, $p < .001$) and state mindfulness subscales of curiosity (r = .46, $p < .001$) and decentering (r = .37, $p < .001$). Overall, these findings suggest that the increased state mindfulness after a brief mindfulness intervention is linked with better basketball free throw score (Figure. 4).

Insert Figure 4 about here)

Given the existence of these associations, we proceeded to assess whether or not the change of state mindfulness scores met the criteria of being a 'mediator' of the association between mindfulness training and change of basketball free throw scores using macro PROCESS (Hayes, 2013). Results showed that the mindfulness training was positively associated with basketball free throw (direct effect; $b = 1.84$, $p = .02$). Changes in state mindfulness mediated the relationship between the mindfulness intervention and performance. Specifically, Mindfulness training was positively related with state mindfulness changes (mediation condition 2; b= 1.79, p = 0.01) and state mindfulness changes were significantly related with basketball free throw changes (mediation condition 3; b = .606, p = .01). The bias-corrected percentile bootstrap method with generated 5000 Bootstrapping samples showed that the indirect effect of mindfulness training through state mindfulness was 1.09 (95% C.I.: 0.26, 1.96). The mediation effect of state mindfulness accounted for 36.8% of the total effect of the mindfulness training on the basketball free throw. Hence, state mindfulness partially mediated the association between mindfulness training and basketball free throw (Figure 5).

(Insert Figure 5 about here)

Discussion

The purpose of this study was to investigate the effects of a short period of mindfulness practice on a free throw shooting task under pressure following ego depletion (examined here using a classical inhibitory task). Of particular interest, we found that in comparison to the control group, who had only a trivial change in their free throw performance from pre-test to post-test (ES= -0.13), participants in the depletion group had a large decrease in performance (ES= -1.28), and participants in the mindfulness group had a moderate increase (ES=0.48) in performance. Furthermore, participants in the depletion–mindfulness group showed a trivial change in their performance (ES= -0.14). This pattern of results not only suggests that mindfulness may help athletes improve their performance in perceptual-motor tasks under pressure, but also that a brief mindfulness intervention may effectively mitigate the influence of ego-depletion on the performance of these tasks.

According to the strength model, self-regulation is dependent on a limited resource, that is, being consumed and thus depleted by acts of self-regulation (Baumeister & Vohs, 2018). Under normal conditions, when this resource is replete, the mind can properly maintain central control and protect against functional impairments resulting from high pressure conditions (Englert, 2016; Englert et al., 2015). High pressure conditions lead to the dominance of the bottom-up, stimulus-driven attentional system (Eysenck, Derakshan, Santos, & Calvo, 2007), which disrupts individuals' attentional processes and harms performance in selective attention tasks (Corbetta & Shulman, 2002). However, as short-term mindfulness training is associated with 'top–down' emotion regulation (Chiesa, Serretti, & Jakobsen, 2013), it may aid superior performance in fine perceptual-motor tasks (e.g., dart throwing) by inhibiting irrelevant impulses and maintaining the focus on the task at hand (Eysenck et al., 2007; Wilson et al., 2009). Therefore in our study mindfulness training may have helped athletes to restore this resource needed to maintain self-control and may have played an important role in managing distracting stimuli and maintaining attention on task relevant information (the rim of the basket). Greater attention towards pertinent thoughts and feelings related to the goal helps meditators to actively acknowledge moment-by-moment affects that signal the need for self-control (Yusainy & Lawrence, 2014). Taken together, these results suggest that individuals who are generally more mindful tend to be better at using their attentional resources and regulating themselves.

In support of our results, Friese et al. (2012) showed that a brief mindfulness induction was more effective than an active control group in mitigating the depleting effects of an emotion suppression task on a subsequent psychological attention task. In addition, a brief 3-min active relaxation exercise helped participants to recover from a depleted self-control strength condition, leading to prevention of impaired sport performance (Englert & Bertrams, 2016; Tyler & Burns, 2008). However, contrary to the findings of Stocker et al. (2018) and Yusainy and Lawrence (2015), we found an effect of mindfulness on shooting performance that can be partly attributed to the mitigation effects of ego-depletion on basketball free throw. Therefore, our results support the idea that mindfulness seems to be particularly appropriate for precision perceptual-motor tasks, as it not only helps to improve performance in non-depleted athletes, but also prevents performance decrements in depleted athletes. These discrepancies can be explained by the different nature of the tasks in our study compared to the task used by Stocker et al. (2018). While, endurance activities require resistance to fatigue and discomfort, and the need to override the urge to stop, basketball free throws are fine perceptual–motor tasks that require accurate hand–eye coordination, which are highly dependent on self-control (Englert, Bertrams, Furley, & Oudejans, 2015; Wilson et al., 2009). This task requires selective attention to block out irrelevant, potentially distracting stimuli (e.g., audience in the stands, task-irrelevant, worrisome thoughts) and to keep the focus of attention on task relevant information (e.g., the rim of the basket). In fact, Bühlmayer, Birrer, Röthlin, Faude and Donath (2017) provided evidence in support of the efficacy of mindfulness in improving athletes' performance in precision sport tasks such as shooting and dart throwing. Therefore, implementing mindfulness into athletes' daily and training routines may constitute a performance-enhancing complementary approach to regular training and competition. Another possible explanation may lie in our study participants' mindfulness experience. In our study, participants were first familiarized with the mindfulness concept and then attended three introductory sessions. However, the participants used by Stocker et al. (2018) were inexperienced in mindfulness, which may have influenced their expectations of success in its use. In addition, it is possible that longer mindfulness interventions than the one used in their study (3 min) are necessary to enhance of sport performance, through improvement of mindful states. However, more studies are needed to examine the dose/response relationship between state mindfulness and sport performance. Therefore, future research should explore the dose/response relationship between mindfulness training and ego-depletion in sport performance.

In line with our hypothesis, participants exposed to the mindfulness intervention reported higher state mindfulness scores than participants from the control group. In addition, increased state mindfulness at post-test was positively associated with free throw performance. As previously mentioned, mindfulness practice has been shown to have a beneficial effect on the mechanisms involved in self-control, such as cognitive flexibility, executive functioning (i.e., cognitive processes), emotion regulation, and attention control (Arch & Craske, 2006; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). These mechanisms may justify the beneficial effects of mindfulness training on athletes' self-control that was observed in the current study. Nevertheless, given that state mindfulness level explained only one third of the variance in free throw performance change, it is likely that there are other processes that mediate the effect of brief mindfulness training on improved performance.

Nonetheless, we can speculate that the improved state mindfulness after the intervention helped participants' performance due to increasing awareness of acute inner experiences (Brown & Ryan, 2003) and feelings of relaxation (Baer, 2003), which in turn may have helped to enhance self-control function

(Tyler & Burns, 2008). Exactly how a short period of mindfulness undoes ego-depletion effects was not definitively answered by the current study and further studies are needed to help clarify this issue. Mental fatigue research has demonstrated impaired performance and alterations in prefrontal cortex activation following effortful cognitive task exposure (Pires et al., 2018). Changes in prefrontal cortex activation may impair top-down modulation of behavior, thereby influencing psychological responses such as ratings of perceived exertion, motivation, emotional arousal and attention allocation (Pires et al., 2018). There is convincing evidence that mindfulness is associated with brain activation and/or connectivity of prefrontal cortex that enhances attention and 'top–down' emotional regulation (Marchand, 2014). Additionally, mindfulness training has been shown to increase left-sided anterior brain-activation, which in turn relates to more adaptive responses to negative or stressful events, specifically faster recovery after negative emotional states (Davidson & Kabat-Zinn, 2004). This interpretation merits verification in future studies using brain imaging.

Another mechanisFm that may justify the effects of mindfulness concerns athletes' ability to process information more effectively during reinvestment and choking under pressure processes. Those individuals who are higher in reinvestment are more likely to perform poorly under pressure compared to low reinvestors. For example, pressure manipulation in a basketball free throw task led to reinvestment of attention in that task (Otten, 2009). It can be argued that mindfulness may prevent reinvestment, as it encourages a non-judgemental acceptance of performance conditions, facilitating automaticity of movement execution. This potential mechanism merits empirical verification.

Our study is well controlled and novel. However, there are limitations that need to be considered. Firstly, the task chosen to induce ego-depletion is not sport specific. Given that no sport-specific depletion tasks have ever been identified, we have selected a task that has been successfully applied in a self-control study (Brown & Bray, 2017). Nevertheless, it has been shown that self-control strength is not domain specific (Hagger et al., 2010) and several studies have recently supported the idea that depleting cognitive tasks disrupt subsequent physical function (Bray et al., 2011; Bray et al., 2008; Englert & Bertrams, 2012; Englert & Wolff, 2015; McEwan et al., 2013), which further supports our methodological choice. In addition, we used a modified Stroop color-word task that included congruent trials, where the word content matched the print color, as an active control condition (for ego-depletion group). This task was selected because it is not cognitively challenging and does not require self-control (Baumeister et al., 2007). However, participants who received this sham self-control intervention (i.e., control and mindfulness groups) also appear to have been somewhat ego-depleted. Therefore, it is possible that this sham self-control intervention might not have been a true control. Several researchers have argued for the use of better control tasks that require low cognitive effort, such as watching a neutral documentary, (e.g., Brown & Bray, 2017); this possibility needs to explore in future studies.

Secondly, although the mindfulness intervention improved state mindfulness, we did not investigate whether mindfulness or ego-depletion also affected athletes' relaxation state. This issue seems important, because it has been shown that active relaxation can counteract negative effects of ego depletion on free throw shooting scores (Englert & Bertrams, 2016). Given the evidence that mindfulness leads to relaxation (Baer, 2003), higher levels of relaxation may explain potential group differences in free throw shooting scores. Therefore, future studies should ascertain whether mindfulness exerts any potential effects on athletes' relaxation or activation levels.

Third, we used a 15-min audio recording of a natural history text of Iran as an active control condition. However, it is possible that this sham mindfulness intervention might not have been a true control. If the participants found the task boring, they may have been equally depleted. Although we cannot confirm this, this should be considered in future studies.

Fourth, while a 15-min mindfulness intervention can be used in preparation for competition or when athletes are on the bench, it is not always feasible during an actual game. Hence, the challenge of developing interventions that are short enough to be applied in real world settings without losing their effectiveness remains an important consideration.

Fifth, we did not check whether participants perceived the free throw task to be a high pressure situation. However, the use of audio messages to induce stress has been successfully applied in previous studies (Englert & Bertrams, 2012; Englert et al., 2015) to create stressful conditions.

Sixth, our study did not include a complete factorial design given that a low pressure manipulation was not used because in real world scenarios tournaments occur under high-pressure conditions. To create high pressure, we exposed participants to distracting audio messages and informed them that individual and team performances would be ranked and made public among

participants. Although, these procedures have been used in previous studies (Englert & Bertrams, 2016; Englert et al., 2015), it is unknown whether, in the present study, this manipulation successfully changed perceived pressure. Hence, in addition to the incorporation of a manipulation check, future studies should actively manipulate pressure to ascertain whether the effects of brief mindfulness interventions on ego-depletion in basketball free throw differ as a function of varying degrees of pressure (Tenenbaum et al., 2009).

Finally, our study participants were players from Iran's second and third tier competitive leagues. Therefore, the results may not be generalizable to athletes of differing abilities and levels or non-athletic populations. We suggest that future studies should test whether the effects of self-control strength depletion are reproducible in other performance tasks and with athletes of different levels.

In conclusion, this research is one of the first studies to support the beneficial effects of mindfulness in improving performance and allowing recovery from ego depletion during a sport task. Future studies should continue to explore the potential mechanisms through which mindfulness impacts performance. Although replication studies are needed, coaches and sport psychologists are encouraged to discuss with their athletes the benefits and applications of mindfulness.

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Table 1. Descriptive statistics (Means± SD) by group (DG: Depletion group; MG: mindfulness group; D-MG: depletion-mindfulness group; CG: control group) for the screening and baseline measures and ANOVA results

Characteristics	DG Mean± SD	MG Mean± SD	D-MG Mean± SD	CG Mean± SD	f	p-value
Age (y)	27.51±4.52	28.82±4.04	29.24±3.42	28.76±4.28	0.69	0.61
Height (cm)	191.23±7.75	193.12±8.68	196.34±6.34	192.85±7.14	1.2	0.32
BMI (kg/m^2)	20.93±1.76	20.23±1.78	20.75±1.87	20.43±2.43	0.56	0.72
Sports history (y)	7.72±2.28	7.44±2.37	7.85±2.67	8.87±2.13	1.4	0.24
Practice session (n/w)	5.53±1.12	5.81±1.18	5.73±1.13	5.34±1.24	0.85	0.48
Dominant arm, n (right/left)	(14/4)	(13/5)	(17/1)	(16/2)	0.54	0.76
Sport trait anxiety						
SAS-2 worry	10.52±2.76	11.92±3.54	10.86±2.87	11.02±2.84	0.67	0.61
SAS-2 somatic	11.04±3.28	10.08±2.33	10.76±3.43	10.18±2.86	0.57	0.73
SAS-2 concentration	11.32±2.93	10.65±3.52	11.18±3.04	10.65±3.13	0.49	0.87
Depletion Sensitivity	40.12±3.32	39.07±2.34	40.25±3.53	39.34±2.74	0.64	0.69
Affective states						
PANAS Positive	22.13±5.12	20.57±3.72	21.04±3.44	20.86±3.56	0.64	0.63
PANAS Negative	11.68±2.83	12.28±2.53	12.87±2.76	12.56±2.62	0.58	0.72
Trait mindfulness	143.87±18.52	137.11±13.92	141.24±11.38	135.12±14.67	1.3	0.34
Trait self-control	44.67±7.12	46.86±5.76	45.42±6.72	43.63±6.13	0.67	0.52
EDMC	9.74±2.21	4.76±1.10	9.43±1.83	4.72±0.82	51.87	0.001*

DG: Depletion group; MG: mindfulness group; D-MG: depletion-mindfulness group; CG: control group; BMI: Body mass index; SAS-2: *Sport Anxiety Scale-2*; PANAS: Positive and Negative Affect Scale; EDMC: *Ego Depletion Manipulation checks.*

Table 2. Descriptive statistics for the state mindfulness and participants' shooting score by group

Characteristics	DG *(n=18)*	MG *(n=18)*	D-MG *(n=18)*	CG *(n=18)*

	Mean± SD	Mean± SD	Mean± SD	Mean± SD
Pre-state mindfulness	23.43±5.53	24.12±5.33	23.13±3.39	22.43±5.72
Post- state mindfulness	17.92±2.76	31.41±3.34	29.14±4.38	23.18±6.43
Pre-TMS Curiosity	10.93±2.78	11.33±3.43	11.24±2.54	10.27±2.19
Post- TMS Curiosity	8.44±2.43	14.87±1.85	13.42±2.23	10.43±2.28
Pre- TMS Decentering	12.53±4.52	12.76±3.67	11.73±3.34	12.09±4.77
Post- TMS Decentering	9.38±2.93	16.43±3.38	15.72±3.42	12.88±5.28
Pre -BSS (%)	53.23±10.02	52.34±8.76	51.09±8.33	49.34±9.68
Post -BSS (%)	40.73±8.72	56.52±8.44	49.39±8.32	48.14±8.76

DG; Depletion group, MG; mindfulness group, D-MG; depletion- mindfulness group, CG; control group, *TMS; Toronto Mindfulness Scale, BSS; Basketball* shooting Score.

Table 3. ANCOVA analysis for the state mindfulness and participants' shooting score by group

Source	State mindfulness			Shooting score (%)		
	$F_{1, 64}$	P	n_p^2	$F_{1, 64}$	P	n_p^2
Time	3.26	0.08	0.05	0.01	0.85	0.001
Trait mindfulness	3.78	0.07	0.06	1.81	0.18	0.03
Trait self-control	0.12	0.73	0.01	4.30*	0.05	0.06
Depletion sensitivity	2.35	.013	0.04	1.10	0.30	0.02
Trait anxiety	0.08	0.76	0.001	0.08	0.78	0.001
Mindfulness training	36.05*	0.001	0.36	4.40*	0.04	0.06
Depletion condition	7.71*	0.008	0.11	1.57	0.21	0.02

Time × Trait mindfulness	0.53	0.47	0.01	0.02	0.88	0.001
Time ×Trait self-control	0.32	0.57	0.01	0.005	0.95	0.001
Time ×Depletion sensitivity	1.55	0.22	0.02	0.003	0.96	0.001
Time ×Trait anxiety	0.13	0.72	0.001	2.03	0.16	0.03
Time × Mindfulness training	73.33*	0.001	0.53	27.05*	0.001	0.29
Time × Depletion condition	9.98*	0.002	0.13	31.10*	0.001	0.32
Mindfulness training × Depletion condition	0.17	0.68	0.003	0.46	0.50	0.01
Time ×Depletion ×Mindfulness training	4.13	0.06	0.06	4.79*	0.05	0.06

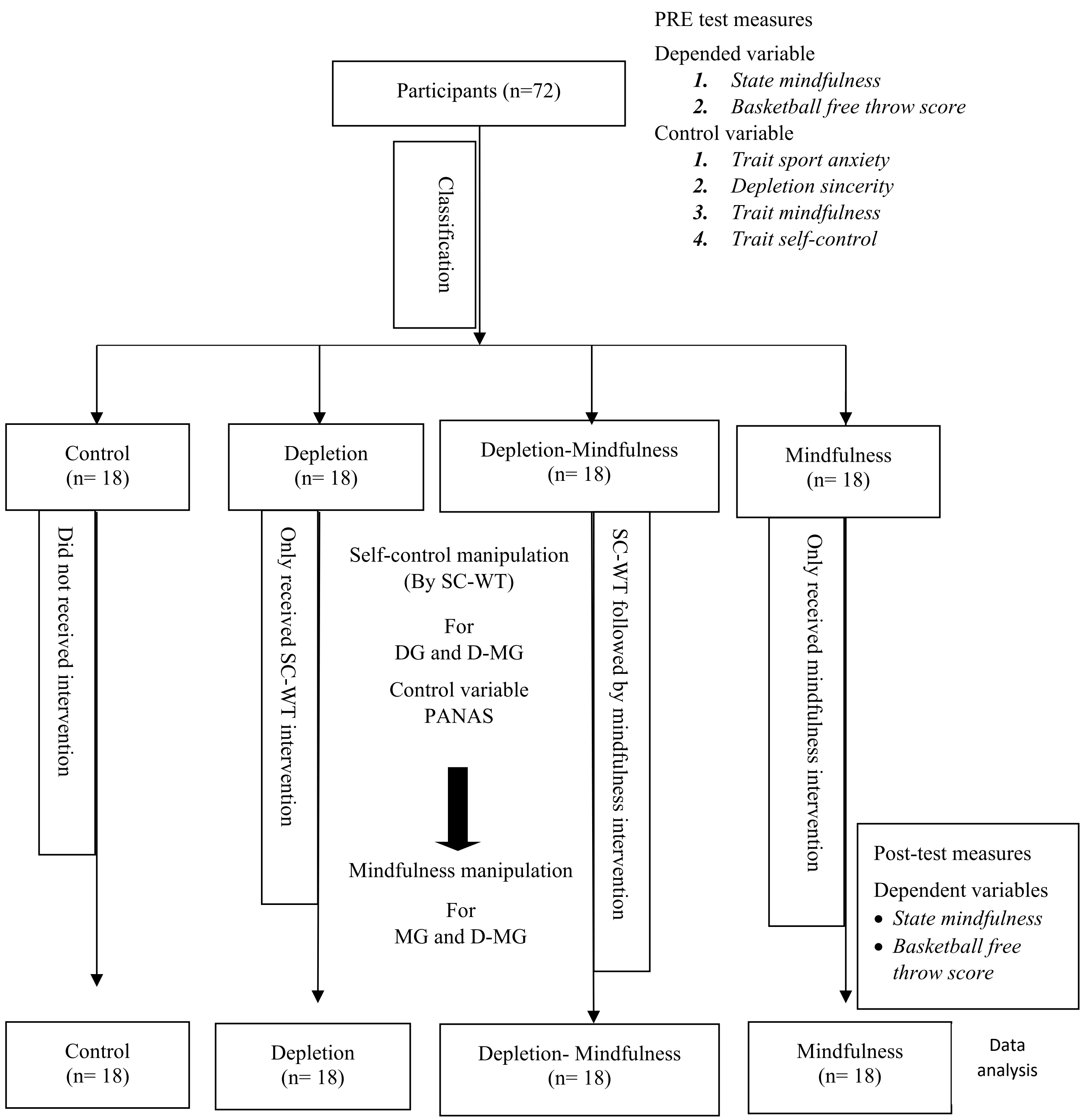

Figure 1 – Study procedure.

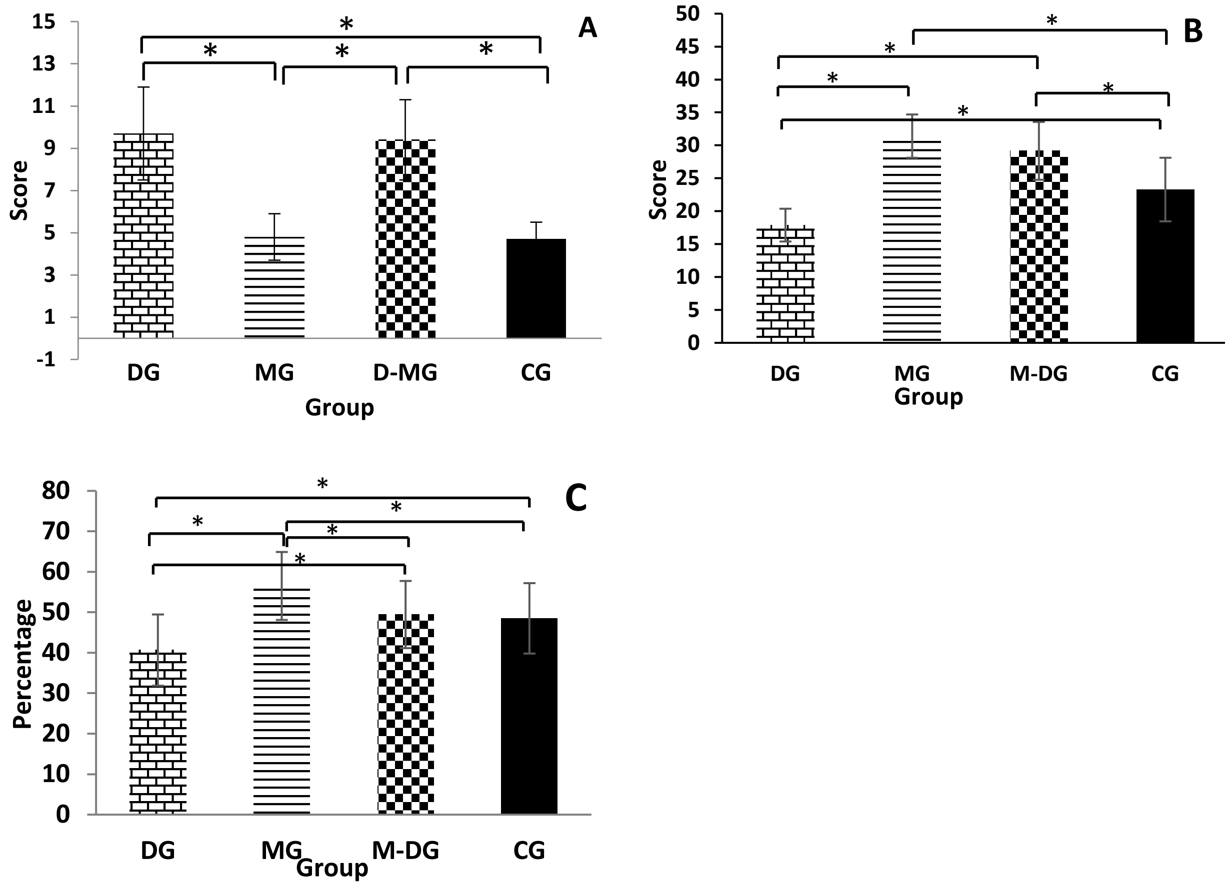

Figure 2. Between group comparisons of A) *ego depletion manipulation checks* score, B) state mindfulness score, and C) basketball free throw score.

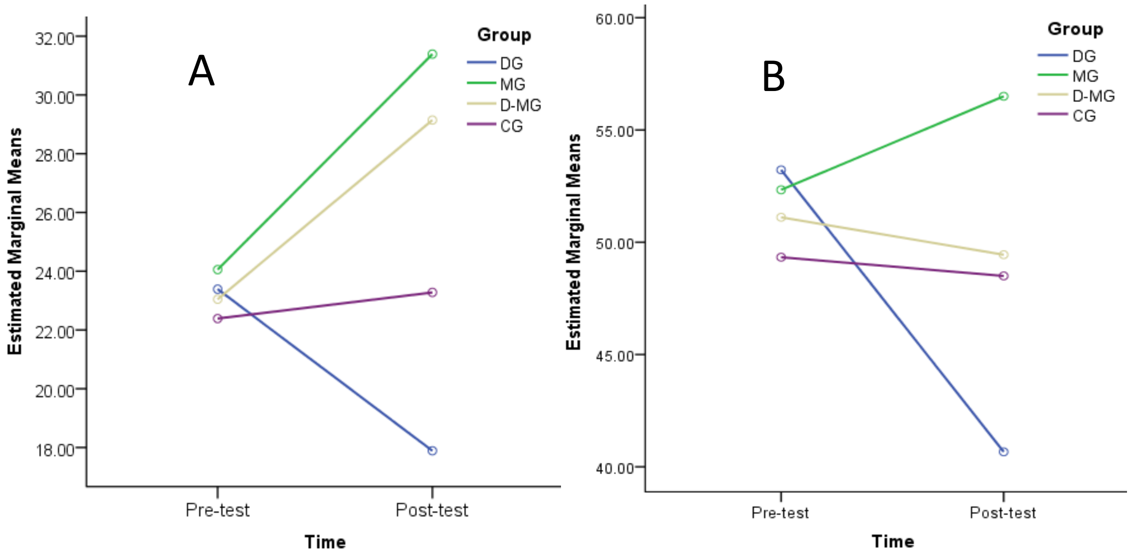

Figure 3. Estimated marginal means for interactions related to A) panel- TMS and B) panel- free throw shooting score. DG = depletion group; MG = Mindfulness group; D-MG = Depletion-Mindfulness group; CG = Control group

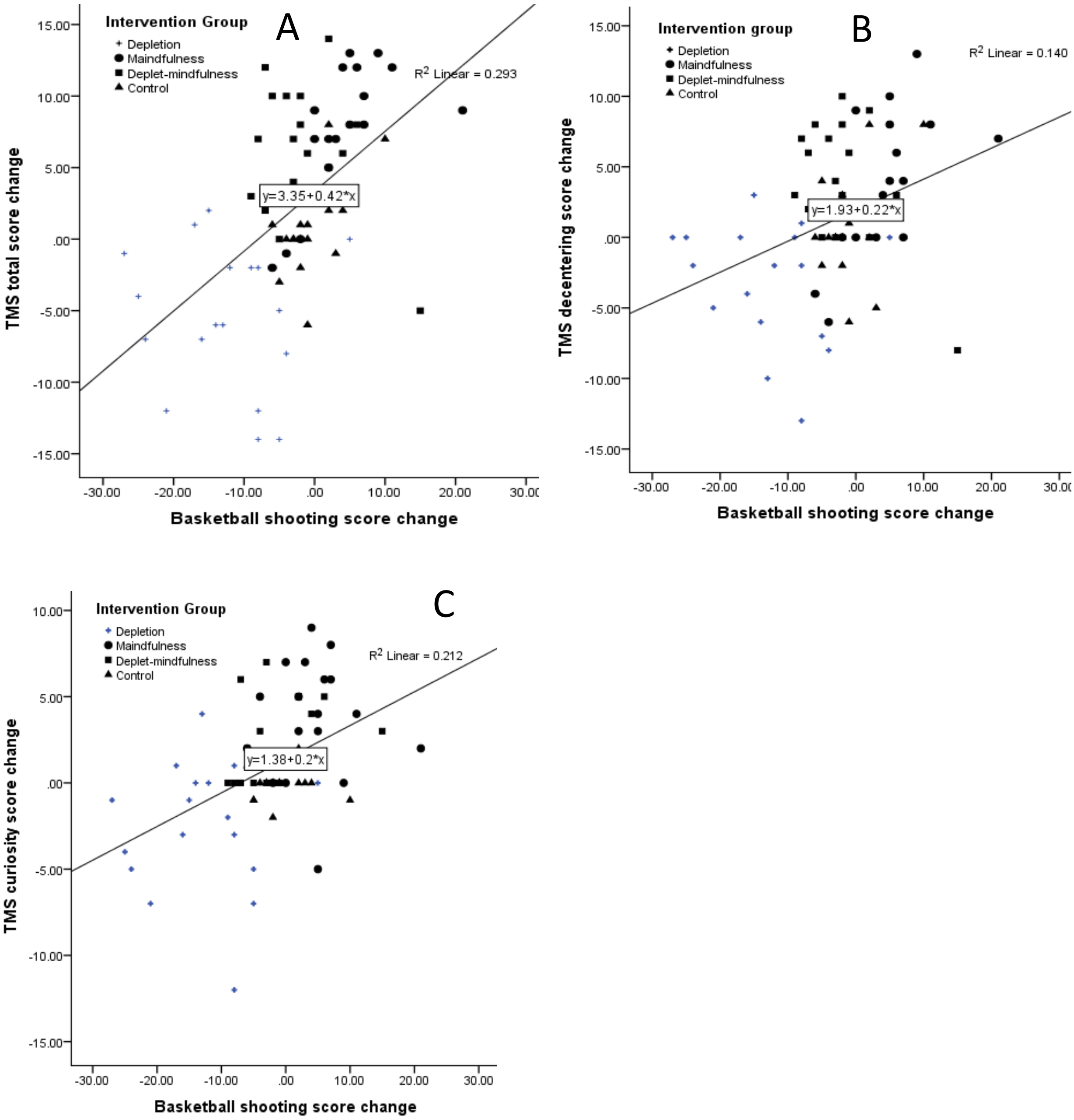

Figure 4. Scatterplot depicting the association between basketball shooting score change and A) total TMS score, B) TMS - curiosity, and C) TMS -decentering score changes achieved during the act of mindfulness meditation. Data points represent individual cases within the experimental conditions. Higher values on the Y-axis denote increased change of state mindfulness from pretest to post test. Higher values on the X-axis denote increased change of basketball free throw score from pretest to post test.

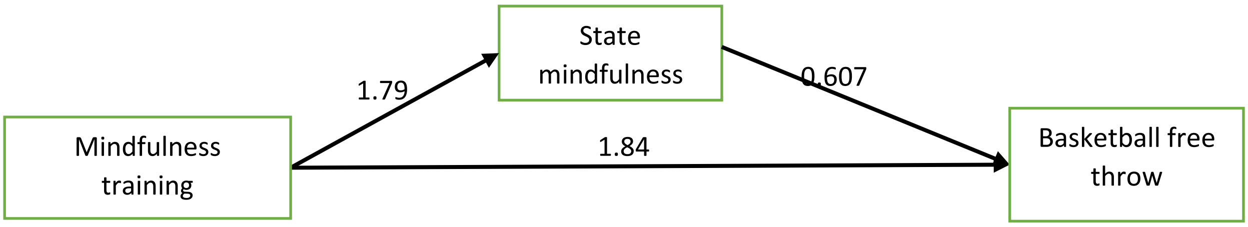

Figure 5.
Path model of state mindfulness as a mediator of the effects of mindfulness training on changes in basketball free throw score (N = 72). Note: Unstandardized coefficients are presented. a × b = 1.09, bootstrap SE = .43, 95% CI: (.26, 1.96). Model R-squared = .15.