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Research article

Acute Effect of Brief Mindfulness-Based Intervention Coupled with Fluid Intake on Athletes' Cognitive Function

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Abstract

During the half time of intermittent team sports, substantial physiological changes relating to acid–base balance and glycemic response affect the second-half performance. Refuel and rehydrate strategy is therefore necessary to be investigated. This field experiment assessed the acute effect of a brief mindfulness-based intervention (MBI) coupled with fluid intake on players' cognitive function in a simulated soccer game. In a single-blinded, randomized, cross-over experiment, 14 male players received three treatments [Control: noncarbohydrate solution + traveling introduction audio; CHO: Carbohydrate (CHO)–electrolyte solution + traveling introduction audio; and CHO-M: CHO–electrolyte solution + MBI] during a simulated half-time break of a soccer game. Participants' mindfulness level, blood glucose and lactate, rating of perceived exertion, and cognitive function performance assessed by the Stroop effect task (ST), Corsi block-tapping test (CBT), and rapid visual information processing task (RVIPT) were immediately measured before, during, and after the trial. Repeated measure ANOVA was used for statistical analysis. The results revealed that: (1) in ST, the CHO_M group performed better than the Control group and marginally better than the CHO group; (2) in CBT, both the Control group and CHO-M group responded faster in the posttest than in the pretest; however, the performance of the CHO group remained the same; (3) the CHO group spent less time on missing numbers in post RVIPT compared with the other two groups. In conclusion, findings of this study provided a preliminary evidence of the positive effect of MBI coupled with CHO intake on athletes' cognitive function, with both positive and negative effect of CHO ingestion.

Key words: Mindfulness; soccer; carbohydrate; team sport.

Introduction

Numerous intermittent team sports require two consecutive periods of play split by a half-time break. The half-time break provides players opportunity to refuel and rehydrate for the second half. Refueling and rehydration during the half-time break are important as substantial physiological changes relating to acid–base balance and glycemic response will affect the first part of the second-half performance (Russell et al., 2015). For instance, physiological changes reduced the total distance covered and the distance covered at a high speed in the first 15 min of the second half compared with the corresponding period of the first half (Lovell et al., 2013). Meanwhile, the increase in response accuracy observed during the first 30 min of the game was attenuated in the first 15 min of the second half (Greig et al., 2007). Thus, it is possible that appropriate recovery strategies adopted during the half-time break will help players to maintain performance in the initial stage of the second half.

Fluid intake, one of the commonly applied recovery strategies during the half-time break, is effective in preventing excessive dehydration caused by water deficit. In addition, different nutrients of the fluid function differently for recovery. Carbohydrate (CHO) is a common element of fluid intake, which is essential for cognitive function as the brain primarily relies on blood glucose for optimal functioning. Furthermore, decision making and skill performance can be influenced by the blood glucose concentration (Hawkins et al., 2018; Hills and Russell, 2018). Faster complex visual discrimination, fine motor speed, and psycho-motor speed in participants with increased blood glucose concentration following a soccer match were observed when compared with a control group (Bandelow et al., 2010). In addition, participants who ingested CHO and electrolytes beverage were able to effectively maintain postexercise shooting skills compared with participants under the placebo condition (Ali et al., 2007).

Other than the fluid intake strategy, psychological interventions can also be used during the half-time break to enhance recovery. The role of psychological skills in athletic performance enhancement is widely recognized (Birrer and Morgan, 2010). Recent studies have demonstrated the potential of using mindfulness-based intervention (MBI) programs to enhance sports performance (Creswell, 2017; Li et al., 2019). Mindfulness is defined as the awareness that emerges from focusing on objects on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment (Kabat-Zinn, 2003). The MBI programs that typically last for 8–12 weeks have shown effectiveness in a broad array of psychological and physical outcomes (Creswell, 2017). In addition, laboratory-based research has revealed the immediate and positive effects of brief MBI (e.g., 5 min meditation) on outcomes such as relaxation following cognitive stress (Azam et al., 2015), the use of attentional focus strategies during movement control (Kee et al., 2012), and working memory (Guleria et al., 2013).

To date, MBI has not been utilized as a tool to maintain or improve the cognitive function during the half-time process in the sports domain. MBI may have potential to benefit players' cognitive function in the initial stage of the second half given its immediate effectiveness in relaxation following cognitive stress, attentional function, and working memory (Azam et al., 2015; Guleria et al., 2013). As fluid intake strategy has become a common strategy during half-time break, the current study therefore aimed to

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investigate the effect of a brief MBI coupled with fluid intake on soccer players' cognitive function after the half-time break. We hypothesized that the combined strategies yield the best effect on cognition.

Methods

Participants

The study participants were student athletes recruited from a university. Fourteen male athletes completed the entire trial (age, 24.3 ± 3.7 years; height, 1.74 ± 0.05 m; weight, 68.3 ± 5.1 kg; maximal oxygen consumption or VO_{2max}, 47.0 ± 4.4 mL/kg/min; average training year, 2.5 years). None of the participants reported history of MBI experience. The present trial was approved by the University Human Research Ethics Committee, and all the participants signed a written consent form.

Study design

This study adopted a three-treatment, randomized, single-blinded, cross-over design. All the participants completed one pretrial and three main trials within one month. At least 72 h washout periods were arranged for participants to sufficiently recover from the prior trial and prevent a carry-over effect of the treatment (Ispirlidis et al., 2008). On the trial day, participants had restrictions on the ingestion of any food or drink containing caffeine, alcohol, and nicotine as they may influence sports performance. Moreover, they were not allowed to perform heavy exercises on the day before the main trial. For the main trails, participants were divided into small groups (i.e., two to three for a group) depending on their VO_{2max} (i.e., players with similar VO_{2max} are grouped together). Each participant was randomized to a sequence of three treatments.

Pretrial: The participants were instructed to finish a beep test after a standardized warm-up session to test the VO_{2max} in the pretrial. They were required to measure the body height and weight and complete a form detailing demographic information. Furthermore, they had to conduct the cognitive function test twice in order to get familiar with the testing process.

Main trial: The main trial was conducted during the daytime (i.e., 9:00 am to 5:30 pm). Two hours before entering the test field, participants had to ingest 500 mL of plain water to be normally hydrated (Gui et al., 2017; Sun et al., 2020). The researcher also instructed them to completely empty their bladders before the main trials.

The Loughborough Intermittent Shuttle Test was developed as the exercise protocol to simulate athletic performance in a soccer game (Nicholas et al., 2000). The entire protocol comprised six 15-min blocks separated by 3-min rest periods. Each block involved 10–12 cycles of activity. Of these cycles, each cycle included a 20-m walk, 20-m maximal sprint, 4-s standing rest, 20-m run at approximately 55% VO_{2max} pace, and 20-m run at approximately 95% VO_{2max} pace. In the main trial of the present study, the researchers instructed the participants to complete the first three blocks of the protocol to simulate the first half of a soccer match.

Baseline tests (e.g., blood sample and cognitive function) were performed before running the blocks. After the participant completed the baseline test, the research assistant individually assessed their rate of perceived exertion (RPE). After the participants completed three blocks, they had a half-time break that simulated the half-time break of a real game. At the beginning of the break, the researchers asked the participants to report their RPE, provide blood samples, and drink one of the two different beverages. The beverages were contained in paper cups without tags. Participants were then instructed to listen to an audio labeled with numbers, followed by the reporting of mindfulness state. Furthermore, participants were asked to perform a standardized brief warm-up for 3 min to avoid injury and maintain performance. Finally, the researchers conducted the posttest for cognitive function, the processes of which were the same as those of the pretest. The detailed protocol was shown in supporting information Figure 1.

Treatments

Three treatments—Control, CHO, and CHO-M were applied during the half-time break.

Treatment CHO involved a CHO–electrolyte solution (Aquarius®, Coca-Cola, USA) containing 4.2 g/mL CHO. Participants were instructed to consume 3 mL/kg in each trial (Foskett et al., 2009). In addition, they were instructed to listen to a 6-min traveling introduction as an active control strategy.

Treatment CHO-M included the same CHO-electrolyte solution as well as a brief MBI comprising a 6-min mindfulness introduction divided into mindful breathing and body scanning.

The Control treatment involved an electrolyte solution without CHO (Aquarius Zero®, Coca-Cola, USA), with the same volume, time, and steps as in the CHO treatment. Participants were also instructed to listen to a 6-min traveling introduction as an active control strategy.

Measurements

Capillary blood: A portable glucose analyzer (Accu-Chek Performa Nano, Roche, Germany) was used to measure blood glucose, and a handheld portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA, USA) was used to assess blood lactate.

Mindfulness state: Referring to a previous study, participants were asked two validated items in the survey ("I felt in touch with my body" and "I focused on my breathing") as a manipulation check of mindfulness induction immediately after completing the experiment (Hafenbrack et al., 2014). A 7-point Likert scale, ranging from 0 (*very slightly or not at all*) to 6 (*extremely*), was used to record the responses. Mindfulness scores were computed by averaging the scores of the two statements. A higher mindfulness score indicated a higher mindfulness level.

Perceived exertion: The Borg 15-point RPE scale, ranging from 6 (*very light*) to 20 (*extremely unbearable*), was used to assess the RPE.

Cognitive function: A test battery of cognitive function comprising the Stroop effect task (ST), Corsi block-tapping test (CBT), and rapid visual information processing task (RVIPT) was administered via a computer.

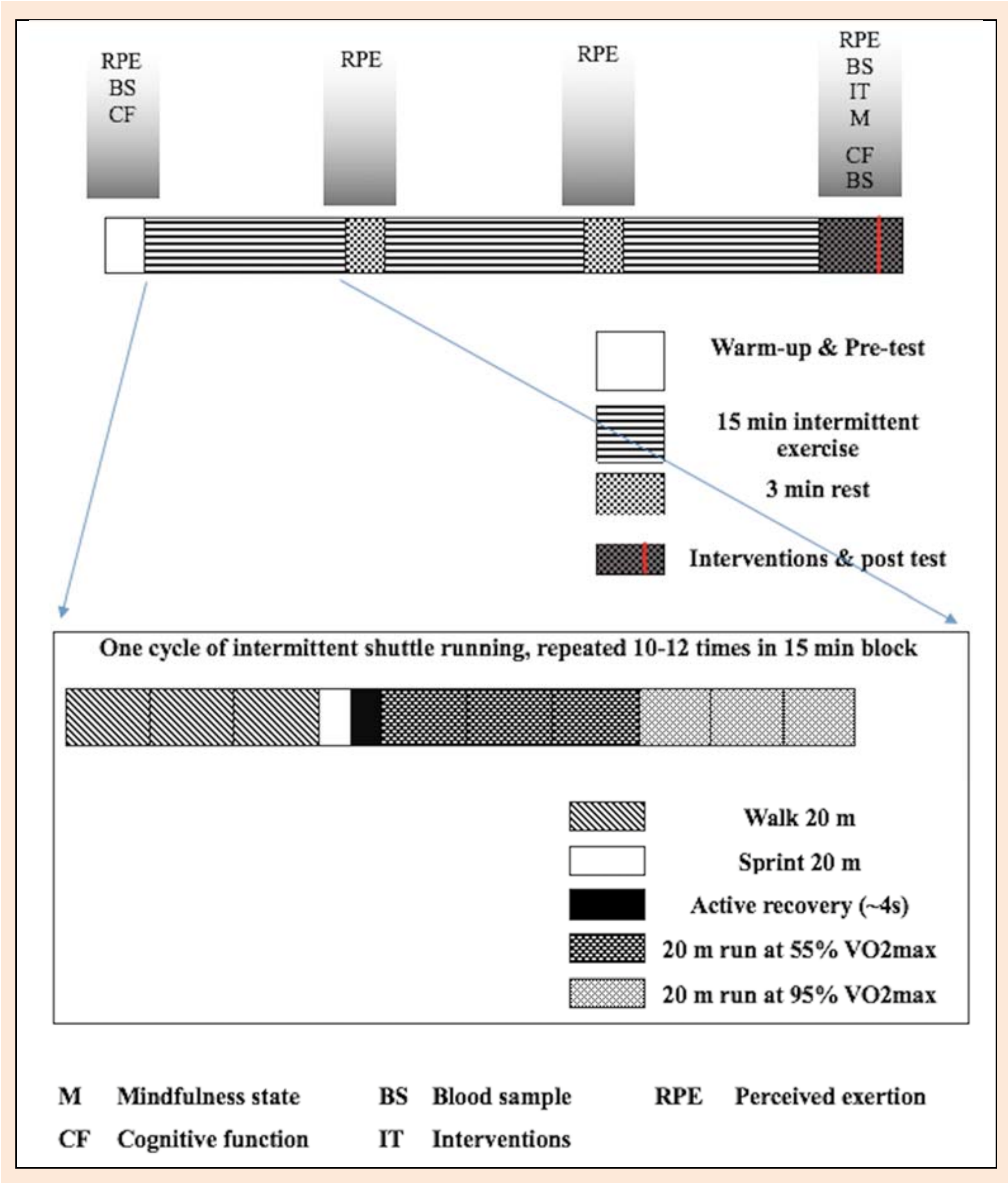

Figure 1. **The detailed protocol.**

The battery aimed at assessing participants' inhibitory control, working memory and sustained attention, which are important for soccer players to respond continuously to a changing and relatively unpredictable situation in the field (Huijgen et al., 2015; Vestberg et al., 2012). It has been successfully applied in several previous studies that examined the effects of exercise and nutrition on sport performance (e.g., soccer; Hogervorst et al., 2008; Sun et al., 2020).

The ST is commonly used to assess cognitive function (Stroop, 1935). This test battery includes two tests: Stroop baseline task (SBT) and Stroop color task (SCT). The test measures the ability to suppress automatic reaction and sensitivity to interfering. Reaction time, accuracy, and score (i.e., a higher score indicates poor performance) were recorded for statistical analysis.

The CBT assesses visuospatial short-term working memory (Berch et al., 1998). Nine identical spatially separated blocks were randomly tapped in a specific sequence through a computer. The participants were required to remember and tap these blocks in the same sequence. The sequences were easy to mimic at the beginning, usually involving three blocks, but became more difficult in the later stages of the participant's performance. The accuracy and reaction time were recorded for statistical analysis.

The RVIPT assesses a participant's sustained attention capacity (Coull et al., 1996). The participants were asked to monitor consecutive sequenced numbers in a stream (100 digit per min or 600 ms per digit) and tap the space bottom if three successive even or odd numbers appeared (e.g., 2–8–4). The accuracy and response time as well as the missed number and time (i.e., time missed by timeout) were recorded for statistical analysis.

Statistical analysis

A two-way repeated measure analysis of variance (ANOVA) was used to detect the main and interactive effects of the treatments (i.e., Control, CHO, and CHO-M) and time (i.e., pretest and posttest) on participants' performance (i.e., cognitive function, blood glucose, blood lactate, and RPE level). One-way repeated ANOVA was used to detect the difference of mindfulness level among three groups. Post hoc analysis with Bonferroni correction was conducted if a significant effect was observed. The significance level was set at $\alpha = .05$. The effect size was referred to by η^2 (partial eta squared) or pre-posttest percentage improvement. Data were presented as mean ± SD. The statistics were run in SPSS 25.0 (SPSS, Inc., Chicago, IL, USA).

Results

Stroop task

The results of ST were shown in Table 1. For the three indices of SBT, no differences were found in accuracy regarding the interactive effect, treatment effect and time effect (all $p > 0.05$). There were also no interactive effect and treatment effect in score and reaction time (all $p > 0.05$). However, a significant time effect was determined for score ($F = 7.14$, $p = 0.02$, Partial $\eta^2 = 0.36$) and reaction time ($F = 5.90$, $p = 0.03$, Partial $\eta^2 = 0.31$). Compared with pretest, the score in posttest improved 5.98%, and reaction time decreased 5.55%.

Regarding the SCT, no interactive and treatment effect were observed in score, accuracy and reaction time (all $p > 0.05$). A significant time effect was detected for score with 9.88% improved performance in posttest ($F = 15.13$, $p < 0.01$, Partial $\eta^2 = 0.54$). Additionally, CHO-M group performed better than Control group in post-test ($P = .04$); and the score of CHO-M group in posttest tended to be higher than that in CHO group ($p = 0.08$). A significant time effect was also revealed for reaction time ($F = 7.23$, $p = 0.02$, Partial $\eta^2 = 0.36$). Participants spent 7.54% less reaction time in posttest than in pretest. However, no different time effect was observed in accuracy ($p = 0.44$).

Corsi block-tapping test

The results of CBT were shown in Table 2. For the reaction time, a significant interactive effect ($F = 5.09$, $p = 0.03$, Partial $\eta^2 = 0.46$) and time effect ($F = 17.55$, $p < 0.01$, Partial $\eta^2 = 0.57$) were detected. Post hoc analysis revealed that the pre–post difference was significant for the Control group ($p < 0.01$) and CHO-M group ($p < p.01$) but not for the CHO group ($p = 0.66$). This implies that the Control group and CHO-M group responded faster in the posttest than in the pretest. Regarding the accuracy, no interactive and treatment effect were observed ($p > 0.05$). However, a significant time effect was detected ($F = 8.85$, $p = 0.01$, Partial $\eta^2 = 0.40$). Compared with pretest, participants performed 3.67% better in posttest.

Rapid visual information processing task

The results of RVIPT were shown in Table 3. For the number correct and time correct, no significant interactive effect and treatment effect were observed (all $p > 0.05$). However, significant time effects were found in both number correct ($F = 30.62$, $p < 0.01$, Partial $\eta^2 = 30.62$) and time correct ($F = 7.00$, $p = 0.02$, Partial $\eta^2 = 0.35$). Compared with pretest, participants performed 12.95% better and spent 2.78% less time in posttest.

Table 1. **Score, reaction time (ms) and accuracy (%) of stroop task. Data are means (±SD).**

		CHO		CHO-M		CON	
	Variables	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Baseline Test	**Score**	11380 (2450)	10776 (1824)	10649 (1176)	10185 (1772)	1085 (389)	799 (253)
	Reaction time	710 (153)	674 (113)	661 (114)	631 (109)	537 (66)	510 (63)
	Accuracy	100 (2)	98 (4)	98 (4)	98 (4)	100 (2)	99 (2)
Color Test	**Score**	22841 (5774)	20834 (5839)	20193 (4882)	17814 (3707) *	25363 (9237)	22990 (6665)
	Reaction time	973 (289)	903 (249)	973 (289)	903 (249)	973 (289)	903 (249)
	Accuracy	93 (7)	93 (7)	94 (7)	95 (5)	94 (76.63)	95 (5)

CHO = Carbohydrate-electrolytes group. CHO-M = Carbohydrate-electrolytes couple with brief mindfulness intervention group. CON = Control group.
* $p < 0.05$ CHO-M vs. CON.

Table 2. **Reaction time (ms), accuracy (%) of corsi block test. Data are means (±SD).**

Variables	CHO		CHO-M		CON	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Reaction time	833 (296)	810 (348) *	827 (385)	667 (332) *	1085 (389)	798 (253)
Accuracy	68 (7)	70 (5)	66 (7)	70 (6)	66 (6)	67 (6)

CHO = Carbohydrate-electrolytes group. CHO-M = Carbohydrate-electrolytes couple with brief mindfulness intervention group. CON = Control group. * $p < 0.05$ Pre vs. Post

Table 3. **Number correct, time correct (ms), number missed, time missed (ms) of rapid visual information processing test. Data are means (±SD).**

Variables	CHO		CHO-M		CON	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Number correct	24 (6)	29 (4)	29 (6)	31 (6)	24 (6)	28 (7)
Time correct	528 (73)	520 (98)	508 (65)	500 (59)	537 (66)	510 (63)
Number missed	10 (14)	9 (13)	9 (15)	9 (16) *	11 (14)	10 (17)
Time missed	7545 (3818)	3317 (2717)**	6511 (4758)	6201 (4014) *	8292 (3189)	5940 (2100)

SD = Standard Deviations. CHO = Carbohydrate-electrolytes group. CHO_M = Carbohydrate-electrolytes couple with brief mindfulness intervention group. CON = Control group. * $p < 0.05$ CHO_M vs. CHO, ** $p < 0.01$ CHO vs. CON

For the number missed, no interactive effect ($F = 0.75$, $p = 0.49$, Partial $\eta^2 = 0.11$) was observed. The main time effect was significant ($F = 27.34$, $p < 0.01$, Partial $\eta^2 = 27.34$). Participants missed 22.06% less numbers in post-test than in pretest. The treatment effect was marginally significant ($F = 3.30$, $p = 0.07$, Partial $\eta^2 = 0.36$). Specifically, CHO-M group had better performance in number missed than CHO group ($p = 0.03$), and tended to be better than control group ($p = 0.09$). No difference was found between control group and CHO group in number missed ($p = 0.69$).

For the time missed, no significant interactive effect and treatment effect were detected (all $p > 0.05$). However, a significant time effect ($F = 5.37$, $p = 0.04$, Partial $\eta^2 = 0.29$) was observed. Participants spent 44.57% less time on missing numbers in the posttest than in the pretest ($p = 0.04$). In post-test, CHO group spent fewer time on missing numbers than Control group ($p < 0.01$) and CHO-M group ($p = 0.05$) separately, whereas no difference was found between control group and CHO-M group ($p = 0.84$).

Mindfulness level

The mindfulness levels of the three groups indicated significant differences ($F = 228.97$, $p < 0.01$, Partial $\eta^2 = 0.97$). Post hoc analysis revealed that participants in the CHO-M group had significantly higher mindfulness levels ($M = 5.32$; $SD = 0.15$) than those in the Control ($M = 2.11$; $SD = 0.19$; $p < 0.01$) and CHO groups ($M = 2.43$; $SD = 0.27$; $p < 0.01$). In addition, no significant difference ($p = 1.00$) was observed between the Control and CHO groups. These findings suggest the brief mindfulness induction was successful.

Blood glucose and lactate

The interaction effect ($F = 0.72$, $p = 0.60$, Partial $\eta^2 = 0.22$) as well as the treatment effect ($F = 0.16$, $p = 0.86$, Partial $\eta^2 = 0.03$) on blood glucose were not significant. However, a significant time effect was observed ($F = 8.83$, $p < 0.01$, Partial $\eta^2 = 0.60$). Participants' blood glucose achieved the highest level after finished exercise protocol ($M = 6.61$, $SD = 0.21$) followed by pretest ($M = 6.33$, $SD = 0.22$; $p = 0.15$) and posttest ($M = 5.74$, $SD = 0.11$; $p < 0.01$).

Regarding blood lactate, no interactive effect was detected ($F = 1.22$, $p = 0.31$, Partial $\eta^2 = 0.09$). A significant main effect was revealed on time ($F = 311.32$, $p < 0.01$, Partial $\eta^2 = 0.96$) but not on treatment ($F = 2.20$, $p = 0.15$, Partial $\eta^2 = 0.27$). Participants' blood lactate achieved the highest level after finished exercise protocol ($M = 6.06$, $SD = 0.33$) follow by pretest ($M = 1.58$, $SD = 0.16$; $p < 0.01$, $r = 0.99$) and posttest ($M = 5.82$, $SD = 0.29$; $p < 0.01$).

Rate of perceived exertion

Regarding the RPE, the main effect of time was significant ($F = 252.32$, $p < 0.01$, Partial $\eta^2 = 0.95$) but that of interaction ($F = .98$, $p = 0.44$, Partial $\eta^2 = 0.07$) and treatment ($F = 0.27$, $p = 0.77$, Partial $\eta^2 = 0.04$) were not significant. Findings suggest that participants' fatigue achieved a peak at the end of first half ($M = 16.24$, $SD = 0.41$) and recovered a little after half-time break.

Discussion

To the best of our knowledge, this study was the first field trial that applied a brief MBI during a simulated soccer half-time break to maintain players' cognitive function performance. Results indicated benefits of applying brief MBI coupled with CHO–electrolyte solution ingestion on participants' performance in the SCT during a half-time break. Meanwhile, in the CBT, the Control and CHO-M groups responded faster in the posttest than in the pretest; however, no changes were observed in participants in the CHO group. In addition, compared with the participants in the Control and CHO-M groups, those in the CHO group spent less time on missing numbers in the RVIPT. Accordingly, the study findings provide a preliminary evidence of a positive effect of MBI coupled with CHO intake on athletes' cognitive function, with positive and negative effects of CHO ingestion.

Acute high-intensity exercise evokes physio-psychological arousal responses, thereby improving the cognitive function (Kujach et al., 2018). This improved cognitive function during the first half of the soccer match was attenuated in the initial stage of the second half due to the half-time break (Greig et al., 2007). Applying a brief MBI coupled with CHO during the half-time break seems to benefit the attenuation, as participants who received MBI performed better in the SCT in this study. The finding was in line with those of previous studies: brief MBI was effective in regulating abnormal condition of human body (Creswell, 2017) and was associated with higher integration of brain networks (van Lutterveld et al., 2017). In addition, MBI enhances attentional function, working memory, and cognitive flexibility followed by a long-term practice (Fabio and Towey, 2018). A meta review study suggested that as a form of induction, mindfulness may most immediately affect attention mechanisms rather than other cognitive domains, often reported as an outcome of longer mindfulness training (Colzato et al., 2015). This may be because MBI could immediately create a cognitive control state that specifically influences focused attention (Colzato et al., 2015) and the capability of reaching an intentional control of both biologic-somatic activities and conscious-unconscious process (Facco, 2017). By influencing attention, negative effects of fatigue (e.g., RPE) can be positively intervened by regulating emotion, thereby subsequently accelerating the recovery of executive function performance (Leyland et al., 2019).

Existing studies on the acute effect of MBI mainly focus on their neuromechanism of immediate effect. Specifically, neuroanatomy has indicated that the effect of MBI practice on cognitive function was found in different areas of the brain (Fox et al., 2016; Herold et al., 2018). Practices conducted in the present study were mindful breathing and body scanning. Mindful breathing is included under focused attention, and body scanning is included under open monitoring. Regarding focused attention, the activations were observed in regions associated with the voluntary regulation of thought and action, and deactivations were observed in regions associated with episodic memory and conceptual processing. Regarding open monitoring, a large effect was observed in the activated regions associated with the voluntary control of action, and low effect was observed in the region associated with cognitive control and metacognitive awareness (Fox et al., 2016). Furthermore, MBI practice significantly affects the activation of prefrontal cortex, which is closely related to cognitive function performance from a neurobehavioral perspective (Herold et al., 2018). A study conducted under the non-exercise state has indicated that mindfulness condition induced more negative deoxygenated hemoglobin values (i.e., stronger activation) in the right hemisphere in the brain compared with that in the control group (Gundel et al., 2018). Considering that the effect of suppressing automatic action and sensitivity was affected by the right prefrontal lateral cortex (Vendrell et al., 1995), the observed increased performance of SCT in the CHO-M group in the present study may be affected by the right prefrontal lateral cortex (Allen et al., 2012). However, given that the number of studies is limited, more explorations are needed to determine the mechanism of our observation.

This study revealed that CHO might be a double-edged sword for cognitive performance. Specifically, the CHO group demonstrated the best performance in post RVIPT in the dimension of reaction time on missing numbers and poor performance in the SCT. In the CBT, the CHO group indicated a slow response compared with those of other groups. Moreover, no significant change in blood glucose was detected even after CHO was ingested. The finding is not surprising given the effects of acute CHO administration on cognitive function (Hawkins et al., 2018). Traditionally, studies have focused on the link between cognitive function and blood glucose availability. These studies have suggested that CHO influences decision making and technical proficiency (e.g., soccer skills or techniques; Hawkins et al., 2018). In addition, CHO was suggested to maintain sports performance through prolonged running ability or soccer skills performed in the latter stages of a match (Baker et al., 2015). However, the common notion that exogenous CHO consumption before and during intermittent exercise maintains glycemia throughout the duration of match-play has recently been challenged (Hills and Russell, 2018). A previous empirical study has determined that a 6% CHO-electrolyte beverage consumption before and during soccer match-play did not improve blood glucose concentrations throughout the second half of an exercise (Russell et al., 2012). Moreover, a review study concluded a detrimental effect and nonsignificant relationships between acute CHO intake and cognitive function performance (Hawkins et al., 2018).

Given that mixed findings were observed regarding the effect of CHO on cognitive performance, the present study provided preliminary evidence suggesting that a brief MBI may attenuate the negative effect of CHO on cognitive function. This may be because MBI positively moderates the attention processes, for which the attentional network in anterior frontal lobes, including anterior cingulate cortex, is considered to generate the attenuate effect. The regulative function of MBI on the frontal neural network over the autonomic nervous system during the cognitive process is suggested (Dickenson et al., 2013). Another possible reason is that the improvement of performance was due to the relaxation effect of MBI following cognitive stress (Azam et al., 2015). However, studies on the roles of a brief MBI in improving athletes' performance during the second stage of a match are inadequate. Regarding the underling effect of CHO–electrolyte fluid intake, more efforts should be made to reveal the potential mechanism.

Limitation

First, a positive effect of MBI on athletes' cognitive function was observed in the first part of the second half; however, not all cognitive function indices were significant. As half-time break is short and precious for a competition, more efforts are required to examine whether MBI is generally effective than other interventions. Second, no neuroscientific instrument was applied to assess the neural change during the trial. The result would be more convictive if such assessment is applied. Third, ingesting CHO is a convenient strategy during the half-time break; however, future research may consider dropping it to distinguish the unique effect of brief MBI on cognitive function. Finally, the observed effects between CHO and CHO_M were significant but small. To make a robust conclusion, more studies with rigorous design and larger sample size are needed.

Conclusion

In conclusion, findings of this study provide a preliminary evidence for the positive effect of brief MBI coupled with CHO intake on athletes' cognitive function during subsequent games after the half-time break.

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Key points

- This is the first field research to examine the effect of a brief Mindfulness-based intervention during a simulated soccer half-time break on players' cognitive function performance.
- Findings provided a preliminary evidence of the positive effect of brief Mindfulness-based intervention coupled with Carbohydrate–electrolyte ingestion on participants' cognitive performance.
- Both positive and negative effects on athlete's cognitive function were found for Carbohydrate ingestion.

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