in Psycholo

important part of cognitive functioning, which supports various activities of individuals and has many different manifestations, such as alerting, selective, sustained, and divided (Tamm et al., 2013; Reigal et al., 2020). Earlier studies have found that attention is related to other aspects of cognitive functioning, such as executive control, learning, and memory (Logue and Gould, 2014; Bialystok, 2015; Campillo et al., 2018). There are two lines of research with respect to the relationship between attention (as well as cognitive functioning) and sports. First, some studies focus on the benefits that physical activities bring on attention in childhood, adolescence, and senescence (Crespillo-Jurado et al., 2019; Xue et al., 2019; Hernández-Mendo et al., 2020). Second, studies have also explored the effect of attention on athletes of different sports with the intention to help them achieve success (Vestberg et al., 2017; Policastro et al., 2018; Hernández-Mendo all tissues of the body underlies emotional awareness (Cannon, 1987; Damasio, 1996; Dolan, 2002; Craig, 2003; Critchley and Harrison, 2013). Sports performances are often impaired by anxiety of competition (Payne et al., 2019). Shooting and archery sports are no exception. Appropriate attention to physical state and accurate perception of internal sensory information are vital to maintain a normal physiological state and awareness of emotion (Craig, 2003, 2010; Critchley, 2005; Wiens, 2005). It is possible that shooters and archers with high interoceptive attention can accurately perceive the internal sensory signals and form an appropriate representation of physiological conditions of the body. This would enable athletes to avoid inappropriate emotions like anxiety that would negatively influence performance and would also help them perform better emotion regulation if inappropriate emotions arise. Therefore, we believed that interoceptive attention is important for shooting and archery, and there can be an advantage in interoceptive attention ability among elite athletes. The first aim of this study was to examine this hypothesis by testing the difference between elite and non-elite athletes of shooting and archery in interoceptive attention ability.

We used the breath detection task (BDT), suggested by Wang et al. (2019), as the interoceptive attention measurement in this study. In BDT, participants are asked to judge whether the respiratory curve displayed on screen is synchronized or delayed when compared with their own breathing rhythm. The control exteroceptive attention task asked participants to judge whether a red dot rapidly appeared on the respiratory curve (i.e., dot flash detection task, DDT). The accuracies of these two tasks represent the interoceptive and exteroceptive attention abilities of the individuals. By using BDT and DDT, Wang et al. (2019) demonstrated the involvement of the anterior insular cortex (AIC) in interoceptive attention. This finding appears to support the notion that an ultimate meta-representation of interoception forms in AIC (Craig, 2010; Critchley and Harrison, 2013). According to Garfinkel et al. (2016), there are three dimensions of interoception, namely, accuracy, sensibility, and metacognitive awareness. Earlier studies have proposed that accurate perceptions of physiological conditions of the body are important for emotion awareness (Critchley, 2005; Wiens, 2005; Craig, 2010). The association of reduced anxiety with greater accuracy of respiration task, suggested by Garfinkel et al. (2016), supported this perspective. Therefore, we focused on accuracy in this study. We chose the respiratory axis of interoception because compared with other axes (e.g., cardiac and stomach), respiration may be under greater voluntary control (Garfinkel et al., 2016). The availability of voluntary control may be important for implementing effective interventions. By comparing the difference in the performance of BDT and DDT between elite and non-elite athletes, we intended to improve our understanding of the relationship between expertise level and interoceptive attention in sports that are characterized by self-paced and far-aiming (e.g., shooting and archery).

If there is a relationship between expertise level and interoceptive attention ability, it preliminarily suggests that interoceptive attention is important for shooters and archers. Then, an important question is how to improve it. Recent research suggests that a promising candidate is mindfulness training. Mindfulness refers to "the awareness that emerges through paying attention on purpose in the present moment, and non-judgmentally to the unfolding of experience moment by moment" (Kabat-Zinn, 2003). Recent studies have found that mindfulness training significantly improved various attention abilities (He and Wang, 2020), such as sustained attention (MacLean et al., 2010; Jha et al., 2015; Bardart et al., 2018), conflict control (Elliott et al., 2014; Becerra et al., 2017), and selective attention distribution (Colzato et al., 2015; Schofield et al., 2015). In particular, a sport-specific mindfulness training program was applied to elite shooting athletes, and attention improvement was found after training (

the principles of the Declaration of Helsinki (World Medical Association, 2013).

Procedure

All of the athletes participated in the BDT and DDT tests. Athletes in the national team then received mindfulness training for 5–8 weeks and took the BDT and DDT tests again. The order of BDT and DDT was counterbalanced in athletes. All athletes completed BDT and DDT in a quiet room. They sat in front of the testing computer in a comfortable position and were required to breathe in a normal and natural way during the whole experiment.

The breath detection task (BDT) was designed to measure interoceptive attention, and DDT was designed to measure exteroceptive attention (**Figure 1**, Wang et al., 2019). The clear perception and autonomous control features of breathing make it feasible to measure interoceptive attention. The findings, suggested by Wang et al. (2019), which object interoceptive accuracy of BDT positively correlated with subjective rating of difficulty of interoceptive task has supported that BDT is a valid measurement of the interoceptive attention. According to Wang et al. (2019), the split-half reliabilities of both BDT and DDT in one sample are 0.86 and 0.85.

In BDT, breathing of the participants was converted into electronic signals by using the A/D converter (USB-1208HS-4AO, Measurement Computing, Inc., Norton, MA, USA), making recordings of their breathing as respiratory healing. MBCT is an intervention designed to help recovered recurrently depressed patients avoid relapse or recurrence. Some of the practices in MBCT were designed for depression, thus inappropriate for the present sample, so these practices were replaced by some content in MBSR (e.g., mindfulness yoga). In summary, the mindfulness training content included body scans, sitting meditation, walking meditation, and mindfulness yoga. Body scans referred to concentrating on the body sensation from head to toe. Sitting meditation referred to attending to and experiencing breath or thought when one is sitting in a comfortable position. Walking meditation referred to observing and sensing the moving parts of the body. Mindfulness yoga referred to focusing and keeping on stretching. Athletes of shooting and archery followed a professional coach to perform mindfulness training once a week for 1.5 h each time. They were asked to conduct a homework practice every day whenever they had time for 15 min.

Data Analysis

The SPSS software version 21.0 (IBM, Armonk, NY, USA) was used for the data analysis. Performance accuracy (%) and discrimination sensitivity (d') were calculated for BDT and DDT, respectively. We, first, compared performances of athletes with chance level by one-sample t-tests for both groups. Then, 2 (Group: National vs. Provincial) × 2 (Task: BDT vs. DDT) ANOVAs of accuracy and d' were conducted to investigate the difference of interoceptive attention and exteroception attention between elite athletes from the national team and non-elite athletes in the provincial team. Finally, 2 (Time: Pre vs. Post) × 2 (Task: BDT vs. DDT) repeated-measure ANOVAs of accuracy and d' were conducted to examine the effect of mindfulness training on interoceptive and exteroceptive attention in elite athletes. In addition, we also conducted a similar ANOVA analysis to examine the effect of mindfulness training for elite shooters and archers separately.

RESULTS

Accuracy and d' of two tasks in both teams were significantly above the chance level (50% and 0 for accuracy and d', respectively). For accuracy, $BDT_{national}$: $t(40) = 12.987$, $p < 0.001$, Cohen's $d = 2.03$; $DDT_{national}$: $t(40) = 24.406$, $p < 0.001$, Cohen's $d = 3.81$; $BDT_{provincial}$: $t(42) = 7.502$, $p < 0.001$, Cohen's $d = 1.14$; $DDT_{provincial}$: $t(42) = 32.286$, $p < 0.001$, Cohen's $d = 4.92$. For d', $BDT_{national}$: $t(40) = 10.138$, $p < 0.001$, Cohen's $d = 1.58$; $DDT_{national}$: $t(40) = 18.474$, $p < 0.001$, Cohen's $d = 2.89$; $BDT_{provincial}$: $t(42) = 6.554$, $p < 0.001$, Cohen's $d = 1.00$; $DDT_{provincial}$: $t(42) = 22.848$, $p < 0.001$, Cohen's $d = 3.47$. Accuracy and d' of two tasks after mindfulness training in national team were also significantly above the chance level. For accuracy, $BDT_{national}$: $t(40) = 26.730$, $p < 0.001$, Cohen's $d = 4.17$; $DDT_{national}$: $t(40) = 28.423$, $p < 0.001$, Cohen's $d = 4.44$. For d', $BDT_{national}$: $t(40) = 18.226$, $p < 0.001$, Cohen's $d = 2.85$; $DDT_{national}$: $t(40) = 21.191$, $p < 0.001$, Cohen's $d = 3.30$.

Differences in Interoceptive Attention Between Groups

Results of 2 (Group: National vs. Provincial) × 2 (Task: BDT vs. DDT) ANOVAs for accuracy (**Table 1**) showed a group effect, $F_{(1, 82)} = 7.835$, $p = 0.006$, partial $^2 = 0.087$, $Diff_{national-provincial} = 6.04\%$, 95% CI = [1.7, 10.3%] and a task effect, $F_{(1, 82)} = 32.189$, $p < 0.001$, partial $^2 = 0.282$, $Diff_{BDT-DDT} = -13.12\%$, 95% CI = [−17.5, −8.4%]. The group × task interaction was also significant, $F_{(1, 82)} = 5.773$, $p = 0.019$, partial $^2 = 0.066$. The simple effect analysis indicated that accuracy difference reached significant level only in BDT between groups, $Diff_{BDT} = 11.50\%$, 95% CI = [3.7, 19.4%], $p = 0.004$. No significant difference was found in DDT, $Diff_{DDT} = 0.50\%$, 95% CI = [−3.6, 4.7%], $p = 0.797$.

Similar results were obtained by 2 (Group: National vs. Provincial) × 2 (Task: BDT vs. DDT) ANOVAs for d' (**Table 2**): group effect, $F_{(1, 82)} = 9.818$, $p = 0.002$, partial $^2 = 0.107$, $Diff_{national-provincial} = 0.676$, 95% CI = [0.247, 1.105]; task effect, $F_{(1, 82)} = 30.127$, $p < 0.001$, partial $^2 = 0.269$, $Diff_{BDT-DDT} = -1.246$, 95% CI = [−1.697, −0.794]; group × task interaction, $F_{(1, 82)} = 4.536$, $p = 0.036$, partial $^2 = 0.052$. The simple effect analysis indicated that d' difference reached significant level only in BDT between groups, $Diff_{BDT} = 1.159$, 95% CI = [0.420, 1.898], $p = 0.002$; $Diff_{DDT} = 0.193$, 95% CI = [−0.287, 0.672], $p = 0.427$.

The results remained significant after controlling for age except the task effects for both accuracy and d'.

TABLE 1 | Accuracy (%) in BDT and DDT between the groups.

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
National ($n = 41$)	83.59 (16.56)	−0.97	−0.05	1.06	91.07 (10.78)	−2.96	12.10	1.47*
Provincial ($n = 43$)	72.05 (19.27)	−0.18	−1.27	0.91	90.53 (8.23)	−1.89	4.33	1.43*
Difference	11.54**	–	–	–	0.54	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
**p < 0.05, **p < 0.01.*

TABLE 2 | Discrimination sensitivity (d') in BDT and DDT between the groups.

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
National ($n = 41$)	2.80 (1.77)	−0.16	−1.27	0.75	3.56 (1.23)	−0.98	1.91	0.70
Provincial ($n = 43$)	1.64 (1.64)	0.56	−0.46	0.87	3.37 (0.97)	−0.31	0.49	0.93
Difference	1.16**	–	–	–	0.19	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
***p < 0.01.*

TABLE 3 | Accuracy (%) in BDT and DDT before and after the mindfulness training in the national team ($n = 41$).

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
Pre	83.59 (16.56)	−0.97	−0.05	1.06	91.07 (10.78)	−2.96	12.10	1.47*
Post	92.12 (10.09)	−2.38	6.84	2.02**	91.07 (9.25)	−3.38	15.20	1.70**
Difference	−8.53***	–	–	–	0.00	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
**p < 0.05, **p < 0.01, ***p < 0.001.*

Effects of Mindfulness Training on Interoceptive Attention in the National Team

Results of 2 (Time: Pre vs. Post) × 2 (Task: BDT vs. DDT) ANOVAs for accuracy (**Table 3**) showed a time effect, $F_{(1, 40)} = 8.636$, $p = 0.005$, partial $^2 = 0.178$, $\text{Diff}_{\text{pre-post}} = -4.27\%$, 95% CI = [−7.2, −1.3%] and a time × task interaction, $F_{(1, 40)} = 9.575$, $p = 0.004$, partial $^2 = 0.193$. The simple effect analysis indicated that accuracy difference reached significant level only in BDT before and after mindfulness training, $\text{Diff}_{\text{BDT}} = -8.5\%$, $p = 0.001$, 95% CI = [−13.5, −3.6%]; $\text{Diff}_{\text{DDT}} = 0$, $p = 1.000$, 95% CI = [−2.9, 2.9%]. Task effect was not significant, $F_{(1, 40)} = 1.792$, $p = 0.188$, partial $^2 = 0.043$, $\text{Diff}_{\text{BDT-DDT}} = -3.22\%$, 95% CI = [−8.1, 1.6%].

Results of 2 (Time: Pre vs. Post) × 2 (Task: BDT vs. DDT) ANOVAs for d' (**Table 4**) revealed a time × task interaction, $F_{(1, 40)} = 11.461$, $p = 0.002$, partial $^2 = 0.223$. The simple effect analysis indicated that d' difference reached significant level only in BDT before and after mindfulness training, $\text{Diff}_{\text{BDT}} = -0.822$, $p = 0.003$, 95% CI = [−1.344, −0.300]; $\text{Diff}_{\text{DDT}} = 0.229$, $p = 0.254$, 95% CI = [−0.171, 0.629]. Neither time effect nor task effect reached significant level, $F_{(1, 40)} = 3.049$, $p = 0.088$, partial $^2 = 0.071$, $\text{Diff}_{\text{pre-post}} = -0.29$, 95% CI = [−0.639, 0.047]; $F_{(1, 40)} = 0.767$, $p = 0.386$, partial $^2 = 0.019$, $\text{Diff}_{\text{BDT-DDT}} = -0.23$, 95% CI = [−0.784, 0.310], respectively.

Effects of Mindfulness Training on Interoceptive Attention in Elite Shooting Athletes in the National Team

Results of 2 (Time: Pre vs. Post) × 2 (Task: BDT vs. DDT) ANOVAs for accuracy (**Table 5**) showed a time effect, $F_{(1, 26)} = 14.856$, $p = 0.001$, partial $^2 = 0.364$, $\text{Diff}_{\text{pre-post}} = -7.0\%$, 95% CI = [−10.7%, −3.3%], and a time × task interaction, $F_{(1, 26)} = 5.619$, $p = 0.025$, partial $^2 = 0.178$. The simple effect analysis indicated that accuracy difference reached significant level only in BDT before and after mindfulness training, $\text{Diff}_{\text{BDT}} = -11.2\%$, $p = 0.002$, 95% CI = [−17.9, −4.6%]; $\text{Diff}_{\text{DDT}} = -2.8\%$, $p = 0.092$, 95% CI = [−6.0, 0.5%]. Task effect was not significant, $F_{(1, 26)} = 1.726$, $p = 0.200$, partial $^2 = 0.062$, $\text{Diff}_{\text{BDT-DDT}} = -4.5\%$, 95% CI = [−11.6, 2.6%].

Results of 2 (Time: Pre vs. Post) × 2 (Task: BDT vs. DDT) ANOVAs for d' (**Table 6**) revealed a time effect, $F_{(1, 26)} = 7.832$, $p = 0.010$, partial $^2 = 0.232$, $\text{Diff}_{\text{pre-post}} = -0.591$, 95% CI = [−1.025, −0.157], and a time × task interaction, $F_{(1, 26)} = 8.863$, $p = 0.006$, partial $^2 = 0.254$. The simple effect analysis indicated that d' difference reached significant level only in BDT before and after mindfulness training, $\text{Diff}_{\text{BDT}} = -1.163$, $p = 0.001$, 95% CI = [−1.828, −0.498]; $\text{Diff}_{\text{DDT}} = -0.019$, $p = 0.937$, 95% CI = [−0.515, 0.477]. The task effect did not reach significant level, $F_{(1, 26)} = 0.728$, $p = 0.401$, partial $^2 = 0.027$, $\text{Diff}_{\text{BDT-DDT}} = -0.315$, 95% CI = [−1.075, 0.444].

TABLE 4 | Discrimination sensitivity (d') in BDT and DDT before and after the mindfulness training in the national team ($n = 41$).

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
Pre	2.80 (1.77)	−0.16	−1.27	0.75	3.56 (1.23)	−0.98	1.91	0.70
Post	3.62 (1.27)	−0.80	0.37	0.93	3.33 (1.01)	−0.69	3.12	0.65
Difference	−0.82**	–	–	–	0.23	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
**$p < 0.01$.

TABLE 5 | Accuracy (%) in BDT and DDT before and after the mindfulness training in elite shooting athletes of the national team ($n = 27$).

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
Pre	80.30 (17.56)	−0.76	−0.46	0.84	89.04 (12.55)	−2.49	8.41	0.99
Post	91.52 (11.41)	−2.25	5.83	1.71**	91.81 (10.00)	−4.21	19.97	1.69**
Difference	−11.22**	–	–	–	−2.77	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
**$p < 0.01$.

TABLE 6 | Discrimination sensitivity (d') of BDT and DDT before and after the mindfulness training in elite shooting athletes of the national team ($n = 27$).

	BDT				DDT			
	***M* (*SD*)**	***S***	***K***	***K–S***	***M* (*SD*)**	***S***	***K***	***K–S***
Pre	2.46 (1.77)	0.09	−1.21	0.57	3.35 (1.36)	−0.81	1.25	0.62
Post	3.62 (1.35)	−0.96	0.53	0.98	3.37 (1.03)	−1.43	5.20	0.97
Difference	−1.16***	–	–	–	−0.02	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.
***$p < 0.001$.

TABLE 7 | Accuracy (%) of BDT and DDT before and after the mindfulness training in elite archery athletes of the national team (n = 14).

	BDT				DDT			
	M (*SD*)	*S*	*K*	*K–S*	*M* (*SD*)	*S*	*K*	*K–S*
Pre	89.93 (12.71)	−1.40	0.87	1.16	95.00 (4.15)	−0.94	1.35	0.64
Post	93.29 (7.13)	−2.18	6.23	1.01	89.64 (7.75)	−0.57	−0.46	0.63
Difference	−3.36	–	–	–	5.36	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.

TABLE 8 | Discrimination sensitivity (d') of BDT and DDT before and after the mindfulness training in elite archery athletes of the national team (n = 14).

	BDT				DDT			
	M (*SD*)	*S*	*K*	*K–S*	*M* (*SD*)	*S*	*K*	*K–S*
Pre	3.44 (1.63)	−0.67	−0.81	0.69	3.96 (0.83)	−0.28	0.75	0.62
Post	3.61 (1.14)	−0.32	0.04	0.47	3.26 (1.01)	1.03	0.14	0.77
Difference	−0.17	–	–	–	0.70	–	–	–

M, mean; SD, standard deviation; S, skewness; K, kurtosis; K–S, Kolmogorov–Smirnov test; BDT, breath detection task; DDT, dot flash detection task.

Comparisons of performances between the national and provincial groups showed that elite shooters and archers outperform athletes from provincial teams in BDT, whereas the two groups did not significantly differ from each other in DDT. A similar pattern was found in d' results which showed that the sensitivity of elite shooters and archers was higher than that of provincial athletes in BDT, but not in DDT. These results suggest that elite shooters and archers indeed have higher interoceptive attention ability. In other words, they can better perceive the somatic and visceral responses or changes and discriminate these signals from noises. According to Critchley and Harrison (2013), the afferent input of the internal body signals serves as sources on which individuals organize cognitive, emotional, and behavioral responses. This may be the mechanism through which the advantage of elite athletes in interoceptive attention exerts its influence. Higher ability in interoceptive attention may be important in the preparation stage during which athletes can adjust their postures based on the current physiological states. It may also benefit the regulation of negative emotions, given the notion that the arising of emotions is inseparable from somatic reactions and visceral signals (Critchley, 2005; Wiens, 2005; Craig, 2010). During the competition, once negative emotion like anxiety arises, accurately perceiving the accompanied physiological changes such as increased heartbeat and muscle stiffness may be the first step to adjustment and further regulation of negative emotions.

The results of mindfulness training showed that the performance of elite shooters and archers improved significantly in BDT but remained unchanged in DDT after receiving mindfulness training. The sensitivity in BDT, but not in DDT, also improved after mindfulness training. Even though elite shooters and archers showed better performance in BDT than provincial players, mindfulness training still improved their interoceptive attention ability. This improvement may benefit from the content of mindfulness training. The content includes keeping focus on a particular point or experience, such as sweeping and mindfulness of breath in a non-judging way (Kabat-Zinn, 1982). Athletes were instructed to redirect their focus to the current attention (e.g., sweeping and breathing) whenever they found their mind drifting somewhere else. Through continuous practice, they were eventually able to keep their attention on bodies for a long period of time, allowing them to quickly and accurately detect physiological changes. We speculated that the neural mechanism that supports this improvement may rely on AIC. On the one hand, the lamina I spinothalamocortical pathway hypothesis indicates that AIC is the destination of transmission of signals that represent physiological conditions of the body. The right AIC integrates the afferent signals and generates an ultimate meta-representation of the primary interoceptive activities (Craig, 2002, 2003, 2010). The finding of AIC activity related to interoceptive attention, suggested by Wang et al. (2019), supports this hypothesis. On the other hand, studies on mindfulness training consistently report increased activity (Lutz et al., 2014; Wheeler et al., 2017; Young et al., 2018), gray matter thickness (Lazar et al., 2005), and gyrification (Luders et al., 2012) of the AIC. So, it may be possible that the mindfulness training increases AIC activity, gray matter thickness, gyrification, or all of them in the elite athletes, and these increased characteristics of

AIC lead to accurate perception of bodily states, which manifest in higher performance of BDT. This may also explain why there was no improvement in the performance of DDT. However, the result that no improvement was found in the performance of DDT does not lead to the conclusion that mindfulness training has no effect on exteroceptive attention. The sensory input of exteroceptive attention has different modalities. We used visual stimulus in this study. Future studies can examine the effect of mindfulness training on other modalities of exteroceptive attention (e.g., auditory stimuli). There are possibilities that mindfulness training may influence the attentional modulation of different perceptual and sensory inputs.

Studies have demonstrated that 4 weeks of mindfulness training could have an influence on dimensions of trait variables in the athletes (Kaufman et al., 2009). Although we initially planned an 8-week training period, due to the different training schedules of elite athletes, it is hard to guarantee the full training period of each athlete. But we managed that all athletes received at least 5 weeks of mindfulness training. A recent review on mindfulness using meta-analysis concluded that a course of 5 weeks would be sufficient to influence the trait mindfulness of an individual (Buhlmayer et al., 2017). Thus, we believed that mindfulness training in this study did exert influence. But it is possible that the additional 3-week training further improved some performance of the athlete compared with the 5-week training. This indicates that our results may reflect a moderate effect of mindfulness training on interoceptive attention. Future studies are recommended to explore the relationship of mindfulness training period and its effect on interoceptive attention in shooting and archery. Some may raise concerns that our experimental design cannot rule out the possibility of practice effect since there was no control group. Should it be a mere practice effect, the performance of the athletes in both BDT and DDT should have been improved. Instead, the results of this study showed an enhancement only in BDT. These results suggest that the improvement of interoceptive attention was not merely a practice effect, but resulted from mindfulness training. Follow-up studies can further investigate the effect of mindfulness training on interoceptive attention in athletes of shooting and archery through random sampling or by adding a control group that does not receive mindfulness training or with brain imaging techniques such as fMRI.

We admitted that there are limitations in this study, and future research can further investigate the role of interoceptive attention in shooting and archery sports in the following aspects. First, our results provide preliminary evidence for the relationship between expertise level and interoceptive attention. But the causal relationship cannot be specified because we did not measure shooting and archery performances. It is possible that the advantage in interoceptive attention results from the high expertise level of elite athletes. Future studies can improve our knowledge about this issue by measuring performances of shooting and archery simultaneously in longitudinal designs. Studies have shown that mindfulness training can improve shooting competition performances (Solberg et al., 1996; John et al., 2011) and facilitates emotion regulation (Wheeler et al., 2017). We speculated that there may be the mediation effects of interoceptive attention and emotion on mindfulness training improving shooting and archery performances. Future studies are encouraged to test these hypotheses by monitoring performances, interoceptive attention during mindfulness training.

Second, the mindfulness training in this study was part of a Psychology Service Program of General Administration of Sport of China for the national team of shooting and archery, thus were only offered to elite athletes. Although it would be more rigorous if the non-elite athletes (provincial team) also received mindfulness training, we believed that the study of mindfulness training in elite athletes also benefits the literature. Our results showed that even though elite athletes had an advantage in interoceptive attention, they still had the possibility of further improvement. We speculated that the effect of mindfulness training has also to be observed in non-elite athletes, and we hope that the findings in this study are also helpful for non-elite athletes. Future studies are welcomed to investigate the effect of mindfulness training on athletes with different skill levels.

Third, in this study, we focused on athlete population only. The comparison between elite and non-elite athletes will give its own contribution to the field. The experiment with non-athlete would further justify the importance of interoceptive attention for elite shooters and ll onot What(f)-550.32(m)0.252795(it)0.19655(pe)

However, in official competitions, athletes are not allowed to bring the biofeedback equipment on the field. Whether the athletes can still accurately perceive their own bodily signals or responses and make timely adjustments without the aid of the instrument remains to be seen. According to our results, mindfulness training can improve the interoceptive attention of athletes without using external equipment that amplifies the signals. Subsequent research can test whether the combination of biofeedback and mindfulness training may further assist athletes of shooting and archery.

CONCLUSION

In this study, we found that when compared with athletes in the provincial team, the elite athletes in the national team performed better in BDT, but not in DDT. This result demonstrated the relationship between expertise level and interoceptive attention ability. Moreover, we found that mindfulness training could improve the BDT performance in elite athletes of shooting and archery. These results intensified our understanding of the role of interoceptive attention in self-paced far-aiming sports and have important implications for the selection and training of shooting and archery athletes. Interoceptive attention may be one of the key cognitive abilities for an elite shooter or archer. From the results, we suggested that mindfulness practice can be included in the training of athletes of shooting and archery.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Committee for Protecting Human and Animal Subjects, School of Psychological and Cognitive Sciences, Peking University. Informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

PL contributed to the experimental design, data collection and analysis, and drafting of the manuscript. QL contributed to the experimental design and data collection. QW contributed to the experimental design, data analysis, and revision of the manuscript. XL contributed to the data collection and examined the study. YW conceived of and examined the study, and revised the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by the National Key R&D Project of China under Grant No. 2017YFC0820200, the National Natural Science Foundation of China under Grant No. 31771205 and 61690205, and the General Administration of Sport of China under Grant No. HT 2018-1.

ACKNOWLEDGMENTS

The authors thank Chuhua Zheng, Xiaoshu Li, Suya Chen, Dandan Xie, Xinrui Mao, Jaegeun Im, and Shuting Yu for their assistance in the data collection.

REFERENCES

Abernethy, B., Maxwell, J. P., Masters, R. S. W., Kamp, J. V. D., and Jackson, R. C. (2007). *Attentional Processes in Skill Learning and Expert Performance*. Hoboken, NJ: John Wiley & Sons, Inc.

Bardart, P., McDowall, J., and Prime, S. L. (2018). Multimodal sustained attention superiority in concentrative meditators compared to nonmeditators. *Mindfulness* 9, 824–835. doi: 10.1007/s12671-017-0822-y

Becerra, R., Dandrade, C., and Harms, C. (2017). Can specific attentional skills be modified with mindfulness training for novice practitioners? *Curr. Psychol.* 36, 657–664. doi: 10.1007/s12144-016-9454-y

Bertollo, M., Robazza, C., Falasca, W. N., Stocchi, M., Babiloni, C., Del Percio, C., et al. (2012). Temporal pattern of pre-shooting psycho-physiological states in elite athletes: A probabilistic approach. *Psychol. Sport Exercise.* 13, 91–98. doi: 10.1016/j.psychsport.2011.09.005

Bialystok, E. (2015). Bilingualism and the development of executive function: the role of attention. *Child Dev. Perspect.* 9, 117–121. doi: 10.1111/cdep.12116

Brener, J., and Ring, C. (2016). Towards a psychophysics of interoceptive processes: the measurement of heartbeat detection. *Phil. Trans. R. Soc. B.* 371:20160015. doi: 10.1098/rstb.2016.0015

Brown, M. M., Arigo, D., Wolever, R. Q., Smoski, M. J., Hall, M. H., Brantley, J. G., et al. (2020). Do gender, anxiety, or sleep quality predict mindfulness-based stress reduction outcomes? *J. Health Psychol.* doi: 10.1177/1359105320931186

Bu, D., Liu, J., Zhang, C., Si, G., and Chung, P. (2019). Mindfulness training improves relaxation and attention in elite shooting athletes: a single-case study. *Int. J. Sport Psychol.* 50, 4–25. doi: 10.7352/IJSP2019.50.004

Buhlmayer, L., Birrer, D., Rothlin, P., Faude, O., and Donath, L. (2017). Effects of mindfulness practice on performance-relevant parameters and performance outcomes in sports: a meta-analytical review. *Sports Med.* 47, 2309–2321. doi: 10.1007/s40279-017-0752-9

Campillo, E., Ricarte, J. J., Ros, L., Nieto, M., and Latorre, J. M. (2018). Effects of the visual and auditory components of a brief mindfulness intervention on mood state and on visual and auditory attention and memory task performance. *Curr. Psychol.* 37, 357–365. doi: 10.1007/s12144-016-9519-y

Cannon, W. B. (1987). The James-Lange theory of emotions: a critical examination and an alternative theory. *Am. J. Psychol.* 100, 567–586. doi: 10.2307/1422695

Colzato, L. S., Sellaro, R., Samara, I., Baas, M., and Hommel, B. (2015). Meditation-induced states predict attentional control over time. *Cons. Cogn.* 37, 57–62. doi: 10.1016/j.concog.2015.08.006

Couture, R. T., Jerome, W., and Tihanyi, J. (1999). Can associative and dissociative strategies affect the swimming performance of recreational swimmers? *Sport Psychol.* 13, 334–343. doi: 10.1123/tsp.13.3.334

Craig, A. D. (2002). How do you feel? Interoception: the sense of the physiological condition of the body. *Nat. Rev. Neurosci.* 3, 655–666. doi: 10.1038/nrn894

Craig, A. D. (2003). Interoception: the sense of the physiological condition of the body. *Curr. Opin. Neurobiol.* 13, 500–505. doi: 10.1016/S0959-4388(03)00090-4

Craig, A. D. (2010). The sentient self. *Brain Struct. Funct.* 214, 563–577. doi: 10.1007/s00429-010-0248-y

Crespillo-Jurado, M., Delgado-Giralt, J., Reigal, R. E., Rosado, A., Wallace-Ruiz, A., Juárez Ruiz de Mier, R., et al. (2019). Body composition and cognitive functioning in a sample of active elders. *Front. Psychol.* 10:1569. doi: 10.3389/fpsyg.2019.01569

Critchley, H., and Harrison, N. (2013). Visceral influences on brain and behavior. *Neuron* 77, 624–638. doi: 10.1016/j.neuron.2013.02.008

Critchley, H. D. (2005). Neural mechanisms of autonomic, affective, and cognitive integration. *J. Comp. Neurol.* 493, 154–166. doi: 10.1002/cne.20749

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Phil. Trans. B. Sci.* 351, 1413–1420. doi: 10.1098/rstb.1996.0125

Dolan, R. J. (2002). Emotion, cognition, and behavior. *Science* 298, 1191–1194. doi: 10.1126/science.1076358

Elliott, J. C., Wallace, B. A., and Giesbrecht, B. (2014). A week-long meditation retreat decouples behavioral measures of the alerting and executive attention networks.

human subjects. *JAMA* 310, 2191–2194. doi: 10.1001/jama.2013.281053

Xue, Y., Yang, Y., and Huang, T. (2019). Effects of chronic exercise interventions on executive function among children and adolescents: a systematic review with meta-analysis. *Br. J. Sport Med.* 53, 1397–1404. doi: 10.1136/bjsports-2018-099825

Young, K. S., van der Velden, A. M., Craske, M. G., Pallesen, K. J., Fjorback, L., Roepstorff, A., et al. (2018). The impact of mindfulness-based interventions on brain activity: a systematic review of functional