Research Article

Effect of intense endurance training with egg white and wheat germ supplementation on cardiopulmonary function in endurance runners

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Abstract

This study investigated the effects of intense endurance training (HIET) combined with egg white and wheat germ supplementation on immune, respiratory, and cardiopulmonary function in endurance runners. In this quasi-experimental study, 24 male endurance runners from Saqqez City were randomly assigned to either a training + supplement group (n=12) or a training + placebo group (n=12). Both groups underwent 8 weeks of HIET (3 sessions/week, 60 min/session, 70-90% heart rate reserve). The supplement group consumed 15g egg white powder (75 kcal) and 17.5g wheat germ powder (78 kcal) daily, approximately 2 hours before training. The placebo group received starch powder. Cardiopulmonary function (VO2max, FEV1), cardiac biomarkers (NT-proBNP, left ventricular stroke volume - LVSV), and inflammatory markers (IL-6) were assessed pre- and post-intervention. Data were analyzed using ANCOVA (SPSS v26, $\alpha=0.05$), controlling for baseline values. Significant improvements were observed in the supplement group compared to the placebo group for VO2max ($F(1,21)=29.482$, $p<0.001$, $\eta^2=0.510$) and FEV1 ($F(1,21)=60.308$, $p<0.001$, $\eta^2=0.742$). IL-6 levels decreased significantly in the supplement group relative to the placebo group, which showed an increase ($F(1,21)=7.848$, $p=0.011$, $\eta^2=0.272$). No significant between-group differences were found for NT-proBNP ($F(1,21)=3.627$, $p=0.071$, $\eta^2=0.147$) or LVSV ($F(1,21)=0.061$, $p=0.807$, $\eta^2=0.003$). Eight weeks of HIET combined with egg white and wheat germ supplementation significantly enhanced maximal oxygen consumption and expiratory function while attenuating exercise-induced inflammation in endurance runners, compared to HIET alone. These findings suggest potential benefits of this supplement combination for improving cardiopulmonary performance and modulating immune responses during intense endurance training.

Key Words: Athletes' heart, High-intensity endurance training, Egg white powder, Wheat germ powder, FEV1, IL-6, VO_{2max}.

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Introduction

Endurance training, often lasting several hours, relies initially on muscle glycogen, blood glucose, and intramuscular fat stores for fuel. As exercise duration increases beyond 90-120 minutes, glycogen depletion elevates reliance on free fatty acid oxidation. While abundant fat stores can sustain prolonged activity, the rate of energy release from fat limits high-intensity endurance performance. Consequently, strategies to augment pre-exercise muscle glycogen and provide exogenous carbohydrates during activity are crucial for maintaining performance (Claessens et al., 2000).

Concerns have arisen regarding exercise-induced cardiac adaptations, with some studies linking endurance training to increased cardiovascular disease risk and sudden cardiac death in young athletes (Neilan et al., 2006). Research indicates the heart secretes Brain Natriuretic Peptide (BNP) and its N-terminal fragment (NT-proBNP) in response to stress or injury, with plasma levels potentially serving as diagnostic markers for heart failure severity (Scharhag et al., 2008). However, the response of NT-proBNP to endurance exercise in athletes remains controversial. Some studies report increases post-exercise (Middleton et al., 2006; Vidotto et al., 2005), while others find no significant change (Bartek et al., 2003), or link increases to impaired function (Hawkridge et al., 2005) or conversely, find no such link. The mechanisms driving NT-proBNP secretion during exercise are unclear, though exercise-induced inflammatory cytokines, particularly Interleukin-6 (IL-6), have been hypothesized to modulate BNP expression (Ma et al., 2004).

IL-6, released during prolonged exercise, is associated with muscle damage (Nieman et al., 2005), left ventricular dysfunction, and heart failure progression (Kanda & Takahashi, 2004). While some research supports a link between IL-6 and muscle injury (Nieman et al., 2005; Yamin et al., 2008), others contest this (Ostrowski et al., 2000). Exercise intensity, duration, muscle mass involved, and individual fitness modulate plasma IL-6 dynamics (Kasapis & Thompson, 2005). Aerobic

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exercise generally benefits body composition and may improve respiratory muscle function and pulmonary indices (Morley et al., 2011), though findings on specific respiratory parameters post-exercise are inconsistent (Beckwée et al., 2019).

Nutritional support, particularly protein-carbohydrate co-ingestion, is vital for endurance athletes to counteract catabolism and support recovery and repair (Zhao et al., 2024). Egg white hydrolysates contain bioactive peptides, including angiotensin-converting enzyme (ACE) inhibitors, with potential health benefits (Garcés-Rimón et al., 2016). Wheat germ, distinct from wheat grain, is rich in protein (albumin, globulin), amino acids, micronutrients, and vitamins, and exhibits immunological activity (Paśko et al., 2025). Egg white and wheat germ are common components of athletic supplements, yet research on their combined effect, particularly on cardiopulmonary and immune function during high-intensity endurance training (HIET), is limited.

Therefore, this study aimed to investigate the effect of 8 weeks of HIET combined with egg white and wheat germ supplementation on immune (IL-6), respiratory (FEV1), cardiopulmonary (VO2max), and cardiac function (NT-proBNP, LVSV) markers in endurance runners. We hypothesized that the combined supplement would enhance these parameters compared to HIET alone.

Materials and methods

Subjects

This quasi-experimental pretest-posttest study with a control group involved male endurance runners from Saqqez City. From an estimated population of 250 eligible runners, 24 participants (mean age ~22 years) were selected via voluntary and convenience sampling. Participants were randomly assigned to either a training + supplement group (n=12) or a training + placebo group (n=12). The study was approved by the Exercise Physiology Committee of Islamic Azad University, Karaj Branch, and all participants provided written informed consent.

Procedures

Anthropometrics

Height, weight, hip/waist circumference, and body fat percentage were measured using a stadiometer, tape measure (5 mm sensitivity), and InBody device, respectively.

Pulmonary function

Forced spirometry (FEV1) was assessed using a Spirodoc spirometer (MIR Company, S/N W001125).

Cardiorespiratory fitness

Maximal oxygen consumption (VO2max) was estimated using the Bruce treadmill protocol, with VO2max calculated via the standard formula (Bruce, 1971).

Blood sampling

Blood samples (5 ml) were drawn from the antecubital vein after a 10-hour fast, 48 hours before starting the protocol and 48 hours after the last training session, between 8-10 AM. Subjects refrained from high-intensity activity for 48 hours prior. Blood for IL-6 analysis was collected in plain tubes, allowed to clot, centrifuged (1500 rpm, 15 min, 4°C), and serum stored at -80°C. For NT-proBNP analysis, blood (5 ml) was collected into EDTA tubes pre-intervention, immediately after the first training session, and post-intervention. Plasma NT-proBNP was measured using a PATHFAST immunoanalyzer and specific kit (Mitsubishi, Japan; sensitivity 125 pg/ml).

Exercise protocol

Both groups performed HIET for 8 weeks (3 sessions/week, 60 min/session: warm-up, main exercise, cool-down). The main exercise involved treadmill running for 21 min at 70-90% of heart rate reserve (HRR = Max HR - Resting HR) (Choi et al., 2017). Intensity was monitored using heart rate monitors (Polar, Finland). Resting heart rate was measured pre-training on session mornings. Sessions occurred in the afternoon (~7 PM) (Saberi et al., 2020).

Supplementation

The supplement group consumed 15g dried egg white powder (75 kcal, protein source) and 17.5g wheat germ powder (78 kcal, carbohydrate source) mixed in 200ml mineral water daily at ~5:00 PM (approx. 2h pre-training). The placebo group received an equivalent amount of starch powder (Nabuco et al., 2018). Supplements/placebo were provided in coded, sealed packages (single-blind design) for 8 weeks. Adherence was monitored (Hida et al., 2012).

Statistical analysis

Descriptive statistics (mean ± SD) summarized the data. The Kolmogorov-Smirnov test confirmed normality. Analysis of covariance (ANCOVA) was used to compare post-intervention values between groups, using pre-intervention values as covariates. Significance was set at $p < 0.05$. Analyses were performed using SPSS software (version 26).

Results

Baseline characteristics (age, weight, height, body fat) did not differ significantly between groups (Table 1). Key outcome measures pre- and post-intervention are shown in Table 2.

Table 1. Baseline anthropometric and physiological characteristics (Mean ± SD).

Variable	Training + Placebo (n=12)	Training + Supplement (n=12)	p-value*
Age (years)	22.3 ± 2.45	22.50 ± 2.65	>0.05
Weight (kg)	72.7 ± 10.13	73.0 ± 10.95	>0.05
Height (cm)	175 ± 5.80	176 ± 6.10	>0.05
Body Fat (%)	18.2 ± 3.72	18.5 ± 4.00	>0.05
IL-6 (pg/ml)	2.84 ± 1.10	2.29 ± 0.17	>0.05
NT-proBNP (pg/ml)	20.29 ± 7.28	20.50 ± 7.81	>0.05
FEV1 (L)	3.11 ± 0.49	3.11 ± 0.48	>0.05
VO_{2max} (ml/kg/min)	50.2 ± 1.3	51.2 ± 2.8	>0.05
LVSV (ml)	79.74 ± 3.48	80.97 ± 3.91	>0.05

*Independent samples t-test.

ANCOVA results (controlling for baseline) revealed significant group differences post-intervention for IL-6, FEV1, and VO_{2max}.

Significant between-group differences emerged in several outcome measures. For IL-6, plasma levels increased in the placebo group but significantly decreased in the supplement group post-intervention ($F(1,21)=7.848$, $p=0.011$, $\eta^2=0.272$). In contrast, no significant difference was observed in the change of NT-proBNP levels between groups post-intervention ($F(1,21)=3.627$, $p=0.071$, $\eta^2=0.147$), though both groups showed increases. Regarding lung function, the supplement group demonstrated a significant increase in FEV1 compared to the placebo group, which showed a slight decrease ($F(1,21)=60.308$, $p<0.001$, $\eta^2=0.742$). Maximal oxygen consumption (VO_2max) also significantly increased in the supplement group compared to the placebo group ($F(1,21)=29.482$, $p<0.001$, $\eta^2=0.510$). Finally, left ventricular stroke volume (LVSV) increased similarly in both groups, with no significant between-group difference post-intervention ($F(1,21)=0.061$, $p=0.807$, $\eta^2=0.003$).

Discussion

This study investigated the combined effect of 8 weeks of HIET and egg white/wheat germ supplementation on cardiopulmonary, cardiac, and immune markers in endurance runners. The key findings were significant enhancements in VO2max and FEV1, a significant attenuation of exercise-induced IL-6 elevation, and no significant between-group differences in NT-proBNP or LVSV compared to HIET with placebo.

The significant improvement in VO2max within the supplement group aligns with evidence supporting protein-carbohydrate co-ingestion for endurance athletes (Zhao et al., 2024). While Karpouzi et al. (Karpouzi et al., 2025) found increased protein intake alone (1.0 to 1.6 g/kg/day) did not further enhance performance during high-intensity functional training (HIFT), our results suggest the specific combination of egg white protein and wheat germ carbohydrates during HIET was beneficial. Subgroup analyses indicate protein co-ingestion with carbohydrates (CHO) may improve muscle glycogen resynthesis more effectively than protein alone, potentially explaining the VO2max benefit observed here (Zhao et al., 2024). Egg white provides a high-quality, bioavailable protein source relevant for athletes (Karpouzi et al., 2025). The lack of a significant difference in LVSV despite the VO2max increase suggests the improvement may stem primarily from peripheral factors (e.g., enhanced oxygen extraction - arteriovenous O2 difference) rather than central cardiac output increases, consistent with Fick's principle (VO2 = Cardiac Output × a-vO2 difference) (Basnet & Rout, 2024). The non-elite status of our participants likely influenced the SV response pattern, plateauing at submaximal intensities (Rowland, 2009). Future research should directly measure a-vO2 difference to confirm this.

The significant increase in FEV1 within the supplement group, contrasting with a slight decrease in the placebo group, indicates a positive effect on expiratory function. While aerobic exercise generally benefits some pulmonary functions (Morley et al., 2011), our results specifically link the supplement combination to improved FEV1 during HIET. Potential mechanisms include reduced airway inflammation (supported by lower IL-6), enhanced respiratory muscle endurance from training combined with improved nutritional support for muscle repair/function, or other bioactive components within the supplements (e.g., ACE-inhibitory peptides in egg white (Garcés-Rimón et al., 2016) potentially reducing bronchoconstriction). Our findings contrast with studies showing no significant post-aerobic exercise changes in respiratory indices (Shen et al., 2023), highlighting the potential role of supplementation. Differences may relate to training protocols, subject characteristics, or the specific supplement intervention.

The observed attenuation of IL-6 levels in the supplement group

Table 2. Dependent variables pre- and post-intervention (Mean ± SD) and ANCOVA results for post-intervention differences.

Variable	Training + Placebo (n=12)		Training + Supplement (n=12)		ANCOVA (Post)		
	Pre-test	Post-test	Pre-test	Post-test	F(1,21)	p-value	η^2
IL-6 (pg/ml)	2.84 ± 1.10	3.24 ± 0.80	2.29 ± 0.17	2.00 ± 0.27	7.848	0.011	0.272
NT-proBNP (pg/ml)	20.29 ± 7.28	23.95 ± 8.52	20.50 ± 7.81	27.73 ± 8.74	3.627	0.071	0.147
FEV1 (L)	3.11 ± 0.49	3.01 ± 0.41	3.11 ± 0.48	3.83 ± 0.54	60.308	<0.001	0.742
VO_{2max} (ml/kg/min)	50.2 ± 1.3	51.2 ± 1.9	51.2 ± 2.8	54.1 ± 5.5	29.482	<0.001	0.510
LVSV (ml)	79.74 ± 3.48	82.67 ± 2.50	80.97 ± 3.91	84.38 ± 3.15	0.061	0.807	0.003

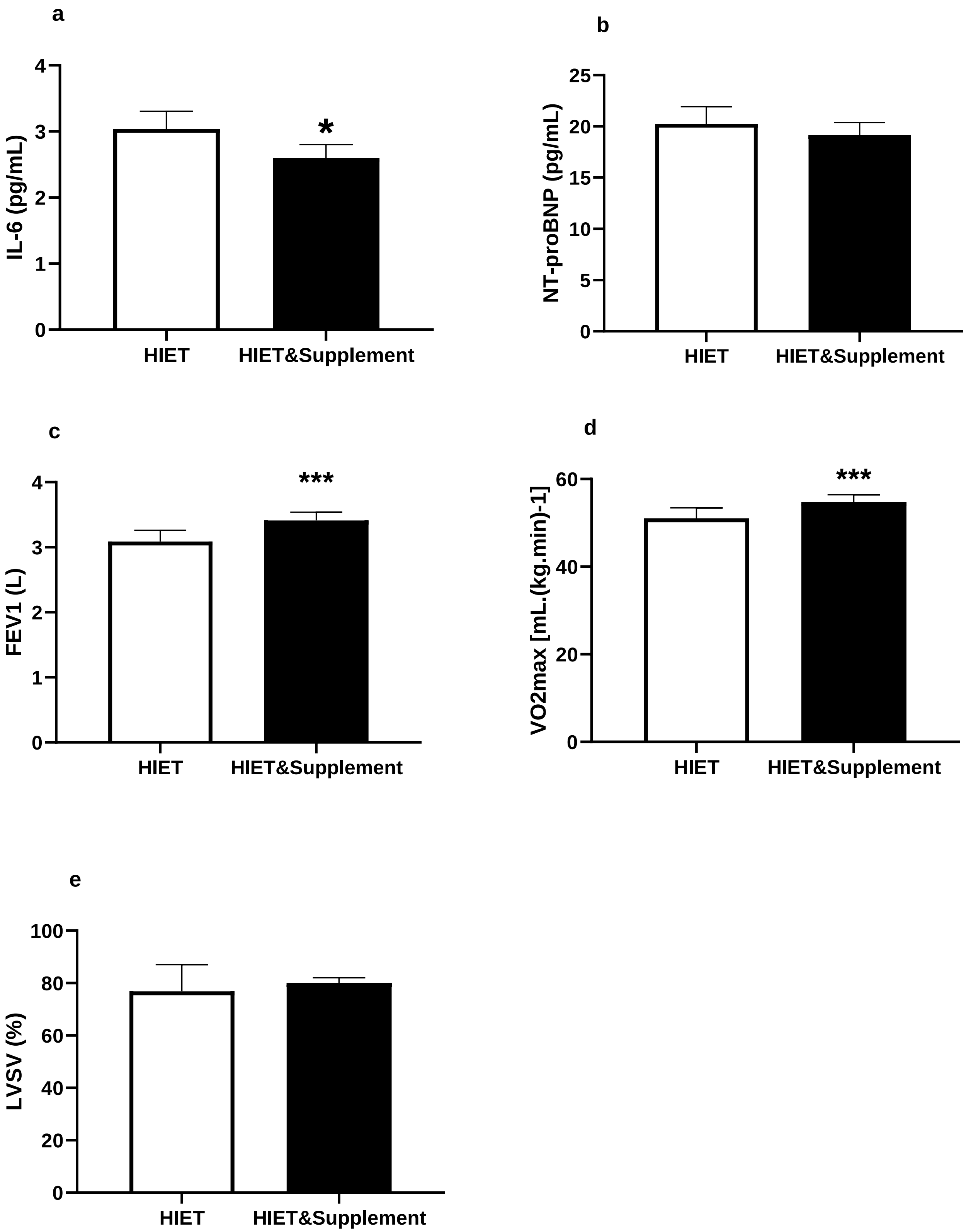

Figure 1. effects of egg white and wheat germ supplementation on measured indices. Data presented as estimated marginal means ± SE from ANCOVA (controlling for pre-test). *p < 0.05, ** p < 0.001 vs. Training + Placebo group. (a) IL-6, (b) NT-proBNP, (c) FEV1, (d) VO2max, (e) LVSV.

compared to the increase in the placebo group suggests an anti-inflammatory effect. Elevated IL-6 is associated with muscle damage during prolonged exercise training and cardiac dysfunction (Kanda & Takahashi, 2004). The increase in the placebo group aligns with studies linking intense exercise to IL-6 release (Nieman et al., 2005; Yamin et al., 2008). The reduction in the supplement group could be attributed to components in wheat germ oil, suggested to reduce inflammatory cytokines like IL-6 and TNF-α (Paśko et al., 2025), or potentially bioactive peptides in egg white hydrolysates. Furthermore, regular training can attenuate the exercise-induced IL-6 response (Gokhale et al., 2007), but our results suggest supplementation provided an additional anti-inflammatory effect beyond training alone. This finding supports the hypothesis linking inflammation and cytokine release to aspects of cardiac strain, although we found no corresponding significant difference in NT-proBNP.

The lack of significant between-group differences in NT-proBNP and LVSV responses suggests that HIET itself was the primary driver of changes in these cardiac markers, and supplementation did not significantly alter this response. The observed increases in NT-proBNP post-exercise in both groups are consistent with some studies, reflecting cardiac wall stress during intense endurance activity (Hansen et al., 2001). The similar LVSV increases also align with the comparable cardiac load experienced by both groups during HIET. The non-significant difference in NT-proBNP change (p=0.071) warrants further investigation with larger samples. The mechanisms of NT-proBNP clearance, involving renal function and endopeptidases (Ohba et al., 2001; Scharhag et al., 2004), likely contributed similarly in both groups.

Limitations include the relatively small sample size and focus on male runners, limiting generalizability. Only IL-6 was measured as an inflammatory marker; assessing a broader cytokine profile (e.g., TNF-α, IL-10) would provide deeper insight. Direct measurement of cardiac output and a-vO2 difference would clarify the mechanism behind the VO2max improvement. Future studies should include female athletes, examine different training intensities/durations, explore the effects of the supplements individually, and investigate long-term outcomes and potential mechanisms (e.g., antioxidant capacity, specific bioactive compounds). Strict dietary control beyond the supplements/placebo would enhance internal validity.

Conclusion

Eight weeks of high-intensity endurance training (HIET) combined with egg white and wheat germ supplementation significantly improved maximal oxygen consumption (VO2max) and forced expiratory volume (FEV1) while attenuating the exercise-induced increase in interleukin-6 (IL-6) in male endurance runners, compared to HIET with placebo supplementation. These results suggest that this specific nutritional supplement combination may enhance cardiopulmonary performance and exert anti-inflammatory effects during intense endurance training. No significant differential effects were observed on N-terminal pro-brain natriuretic peptide (NT-proBNP) or left ventricular stroke volume (LVSV), indicating that the cardiac responses were primarily driven by the training stimulus itself. Egg white and wheat germ powder supplementation appears to be a beneficial nutritional strategy for improving key performance and health markers in endurance athletes undergoing intense training.

What is already known on this subject?

Endurance training, often lasting several hours, relies initially on muscle glycogen, blood glucose, and intramuscular fat stores for fuel.

What this study adds?

HIET combined with egg white and wheat germ supplementation significantly improved VO2max and FEV1 while attenuating the exercise-induced increase in IL-6 in male endurance runners, compared to HIET with placebo supplementation.

Organ Cross-Talk Tips:

- The combined egg white and wheat germ supplementation appeared to modulate the systemic crosstalk during intense training, simultaneously improving cardiopulmonary function (VO2max, FEV1) and reducing inflammatory signaling (IL-6) compared to training alone.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures involving human participants were performed in accordance with the ethical standards of the institutional research committee (Specialized Committee on Exe-

-rcise Physiology of Islamic Azad University, Karaj Branch) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical approval was obtained.

Informed consent Participants signed an informed consent form prior to participation in the study.

Author contributions

Conceptualization: F.F., F.A,; Methodology: F.F., A.N,; Software: F.F., A.N.,; Validation: F.F., A.N.,; Formal analysis: F.F., A.N,; Investigation: F.F., A.N., M.M., F.A,; Resources: F.F., A.N., M.M., F.A.,; Data curation: A.N,; Writing - original draftA.N,; Writing - review & editing A.N,; Visualization: A.N,; Supervision: F.F,; Project administration: F.F,; Funding acquisition: F.F

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