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"HIITing" executive function in pregnancy: effects of prenatal high-intensity interval training on cognitive control – a randomized controlled trial

background
Pregnancy involves dynamic neuropsychological changes, particularly in executive functions such as attention and cognitive control. Although physical activity is known to support cognitive and emotional health, the effects of high-intensity interval training (HIIT) on objective cognitive functioning during pregnancy remain unclear. This study examined whether supervised prenatal HIIT influences executive functioning and explored the role of psychological and personality-related factors in cognitive performance.

participants and procedure
In this randomized controlled trial, 54 healthy pregnant participants with uncomplicated singleton pregnancies were assigned to either an 8-week supervised prenatal HIIT programme or an educational intervention focused on healthy lifestyle and moderate-to-vigorous physical activity (MVPA). Executive functioning was assessed before and after the intervention using the Stroop Colour–Word Test. Psychological well-being, depression, fear of childbirth, health-related quality of life, optimism, and personality traits were also measured.

results
Post-intervention between-group differences in Stroop interference indices were limited; however, the HIIT group demonstrated superior performance in reading-related processing efficiency under congruent conditions. Within-group analyses indicated improvements in executive functioning in both groups. The HIIT group showed broader gains in processing speed, accuracy, and overall task efficiency, while the educational group exhibited greater reductions in interference-related outcomes. Personality traits and psychological variables, including depression, fear of childbirth, and perceived health, significantly predicted cognitive performance.

conclusions
Both prenatal HIIT and educational interventions were associated with improvements in executive functioning during pregnancy, albeit with distinct cognitive profiles. HIIT appeared to support global cognitive efficiency, whereas educational intervention was associated with reduced cognitive interference. Psychological and dispositional factors substantially influenced cognitive outcomes, highlighting the importance of individual differences in prenatal intervention research.

key words
pregnancy; physical activity; psychological factors; cognitive control; high-intensity interval training (HIIT)

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BACKGROUND

Pregnancy is associated with substantial neuropsychological changes, particularly in cognitive domains such as attention, memory, and executive functioning (Iranshahi et al., 2025; Poćwierz-Marciniak et al., 2025). Cognitive functions encompass a broad range of mental processes involved in perceiving, processing, and utilizing information, including attention, learning, memory, and reasoning, whereas executive functions constitute a more specialized subset responsible for regulating, coordinating, and directing goal-oriented and adaptive behaviour (Maruszewski, 2024). A growing body of research suggests that pregnancy may be accompanied by declines in cognitive performance, with several studies documenting diminished outcomes in memory-related tasks (Farrar et al., 2014; Wilson et al., 2013), reduced processing speed (Fiterman & Raz, 2019; Rehbein et al., 2022), and impairments in executive functions such as working memory (Barda et al., 2021; Hampson et al., 2015; Kataja et al., 2017), cognitive flexibility (Rehbein et al., 2022), and response inhibition (Crawley et al., 2003). Subjectively, pregnant women frequently report reduced concentration, memory lapses, disorientation, and difficulties with executive control, particularly during mid- to late pregnancy. These changes have been linked to pronounced hormonal fluctuations characteristic of pregnancy, which are known to influence neural functioning and memory-related processes (Barda et al., 2021). Recent reviews and meta-analyses further indicate that although cognitive changes are often subtle, memory-related alterations are among the most consistently observed effects across studies (Davies et al., 2018; de Groot et al., 2006).

Despite accumulating evidence of pregnancy-related cognitive change, findings across studies remain notably inconsistent, and the mechanisms underlying these discrepancies are not yet fully understood (Nuckols et al., 2025). Increasing evidence, including findings reported by Davies et al. (2018), suggests that such variability is largely attributable to methodological and contextual factors rather than uniform cognitive decline, with the timing of assessment representing a key methodological factor. The timing of assessment appears critical, with more pronounced effects frequently observed in late pregnancy compared to earlier trimesters. Moreover, outcomes vary substantially depending on the cognitive domain assessed, as tasks requiring greater executive control or effortful memory processing are more sensitive to change than simpler attention or recognition measures (Henry & Rendell, 2007). Study design quality also plays a decisive role, as prospective longitudinal studies incorporating pre-pregnancy baseline assessments often report minimal or no objective cognitive differences between pregnant and non-pregnant women, in contrast to cross-sectional designs that are more vulnerable to bias (Christensen et al., 2010). Additionally, contextual confounds – including sleep disruption, increased stress, mood symptoms, and caregiving demands – may intensify subjective cognitive complaints even in the absence of measurable objective deficits (Anderson & Rutherford, 2012). Importantly, some authors propose that pregnancy-related cognitive changes may reflect adaptive reallocation and specialization, particularly within neural systems supporting social cognition and maternal behaviours, resulting in domain-specific advantages alongside modest costs in effortful memory or executive processing (Hoekzema et al., 2017). Collectively, these findings support a framework in which cognitive changes during pregnancy are best conceptualized as heterogeneous, domain-specific, and context-dependent rather than as evidence of generalized cognitive deterioration.

Against this backdrop, there is a growing need to identify modifiable behavioural factors that may buffer pregnancy-related cognitive vulnerability or promote adaptive cognitive functioning. Physical activity has been widely recognized as such a factor, with extensive evidence demonstrating its benefits for both cognitive (Fernandes et al., 2017; Mandolesi et al., 2018) and emotional functioning (Mikkelsen et al., 2017; Schuch et al., 2019). In the general population, regular exercise is associated with improvements in attention, memory (Erickson et al., 2011; Garrett et al., 2024), and executive functioning (Guiney & Machado, 2013), alongside reductions in stress (Herbert et al., 2020), anxiety, and depressive symptoms (Schuch et al., 2019) – processes highly relevant to pregnancy-related neuropsychological change (Barba-Müller et al., 2019; Davies et al., 2018; Hoekzema et al., 2017). Within this context, among different exercise modalities, high-intensity interval training (HIIT) has gained increasing attention due to its time efficiency and robust neurobiological effects (Atakan et al., 2021; Gillen & Gibala, 2014) and modulation of stress-responsive systems (Arvidson et al., 2020). Importantly, these neurobiological and stress-regulatory mechanisms associated with HIIT overlap with pathways implicated in pregnancy-related cognitive and affective changes, such as hormonal fluctuations, neural plasticity, and heightened stress sensitivity (Davies et al., 2018; Hoekzema et al., 2017; Rinne et al., 2023; Younis et al., 2025).

Although vigorous exercise during pregnancy has historically been approached with caution (Gascoigne et al., 2023), accumulating evidence indicates that appropriately supervised and individually tailored HIIT protocols are safe for healthy pregnant women when conducted in accordance with established clinical guidelines (Beetham et al., 2019; Szumilewicz et al., 2022). Empirical support for this proposition is growing. In a randomized controlled trial conducted during the COVID-19 pandemic, an 8-week supervised online HIIT programme led to significant improvements in mental health, including reductions in depressive symptoms, fear of childbirth, and anxiety, while maintaining cardiorespiratory fitness, compared with a self-performed moderate-to-vigorous physical activity (MVPA) and educational intervention in which fitness declined (Wilczyńska et al., 2022). Complementing these findings, a subsequent randomized controlled trial demonstrated that prenatal HIIT induced an increase in hair cortisol levels without adverse psychological consequences and was uniquely associated with improvements in mental well-being, suggesting that the physiological stress response elicited by HIIT during pregnancy may reflect adaptive eustress rather than maladaptive distress (Wilczyńska et al., 2024). Extending this work into the postpartum period, a follow-up randomized controlled study comparing supervised prenatal HIIT with self-performed MVPA reported no detrimental effects on postpartum mental health, with comparable trajectories of depressive symptoms and well-being across groups, while highlighting the potential of prenatal HIIT to support psychological resilience and physical readiness during the transition to motherhood (Walczak-Kozłowska et al., 2025). Collectively, these findings suggest that HIIT, when individualized and clinically supervised, constitutes a safe, feasible, and theoretically grounded intervention during pregnancy, with meaningful implications for affective functioning and potential relevance for neuropsychological adaptation.

AIM OF THE STUDY

Taken together, existing evidence suggests that pregnancy-related cognitive changes, particularly those involving memory and executive control, are subtle, heterogeneous, and inconsistently expressed across studies, with the greatest vulnerability observed in tasks placing high demands on executive cognitive control. At the same time, growing intervention research has demonstrated the psychological safety and affective benefits of prenatal HIIT, although its effects on cognitive functioning during pregnancy remain unexplored. To our knowledge, no published studies have directly examined the impact of HIIT on objective cognitive outcomes in this population, representing an important gap, particularly given that executive functions are both sensitive to pregnancy-related change and highly responsive to physical activity interventions in non-pregnant populations.

Accordingly, the present study aimed to evaluate whether participation in a supervised prenatal HIIT programme is associated with changes in cognitive functioning, operationalized through performance on the Stroop Colour–Word Test, a well-established measure of executive control, selective attention, and cognitive inhibition. In addition to examining cognitive change per se, the study sought to determine whether selected psychological variables are associated with cognitive performance at baseline and following the intervention, and whether stable psychological traits or changeable psychological characteristics contribute to individual differences in cognitive outcomes. Importantly, the absence of cognitive change was also treated as a meaningful outcome, prompting further exploration of factors that may support cognitive stability during pregnancy. Specifically, the study addressed three research questions:

1. Do changes in Stroop test performance between pre-intervention (T0) and post-intervention (T1) differ as a function of experimental condition (HIIT vs. educational control)?
2. Is cognitive performance measured by the Stroop test at T0 and T1 associated with psychological variables and stable psychological traits?
3. Which psychological factors predict post-intervention Stroop performance?

By addressing these questions, this study sought to elucidate the cognitive effects of prenatal HIIT and to clarify the psychological conditions under which cognitive functioning during pregnancy may be altered, preserved, or supported.

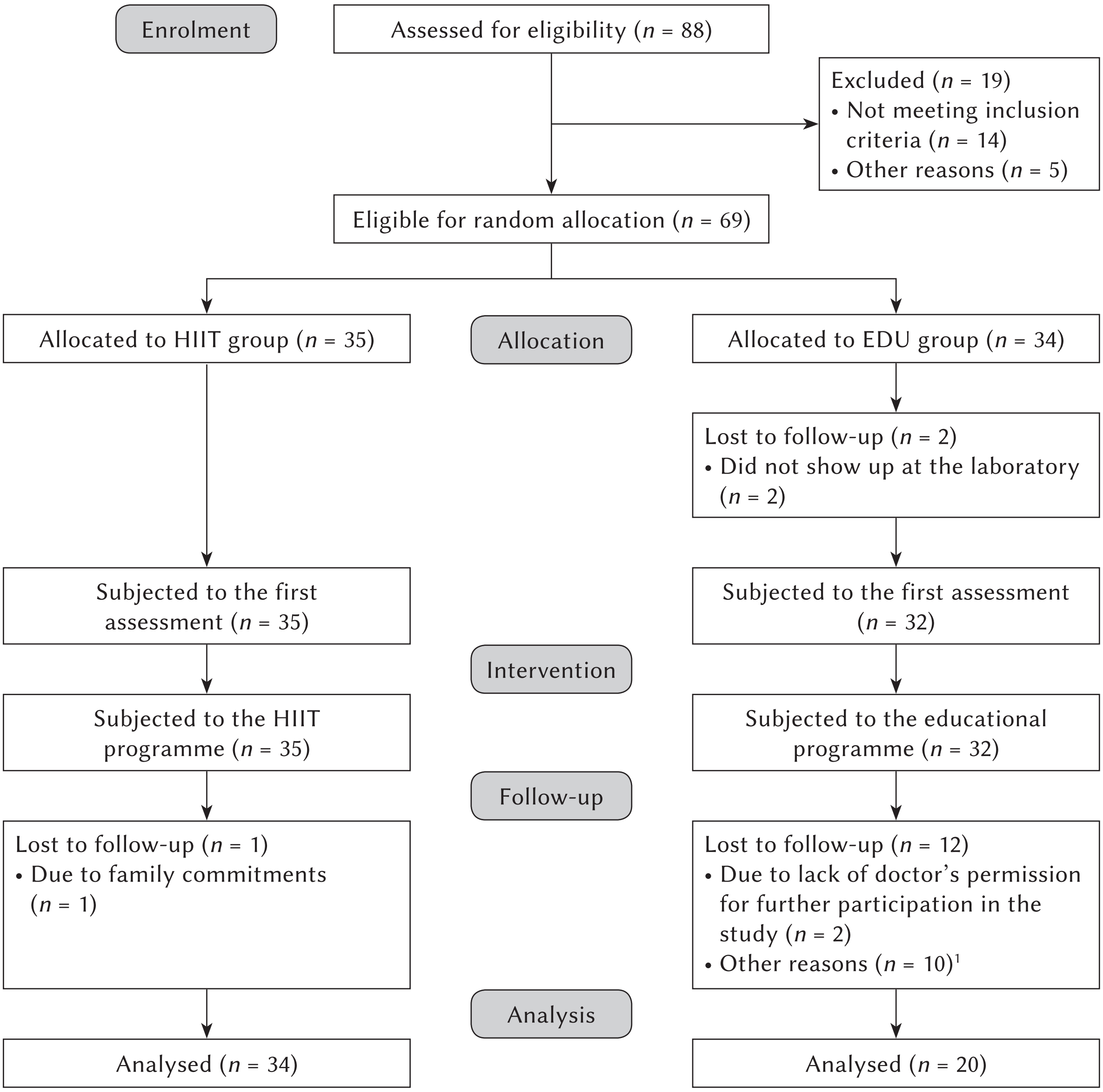
PARTICIPANTS AND PROCEDURE

PROCEDURE

This study was a randomized control trial among 54 Caucasian female participants in uncomplicated, singleton pregnancy who responded to our mass media invitation and volunteered for the study. All participants identified as women; hence the term "women" is used throughout this work. To randomly allocate the participants to the HIIT intervention (HIIT group) or educational intervention (EDU group) and to avoid the contamination effect, as well as to address feasibility and ethical issues during the study implementation, we used the pipeline arm-focused randomization (PAFR) model, based on the assumptions of pipeline randomization (White, 2013) or stepped wedge randomization (Cook et al., 2016). The allocation ratio was 1:1. The flow of the participants through the study is presented in Figure 1. The study was conducted in the Laboratory of Physical Effort and Genetics in Sport in Gdansk, Poland in 2021. There were 34 participants in the HIIT group, who participated in an 8-week HIIT programme. The comparative group consisted of 20 pregnant participants who attended an 8-week educational programme on a healthy lifestyle and physical activity in the perinatal period (EDU group). They were encouraged to perform MVPA regularly on their own. The eligibility criterion was a course of pregnancy

Figure 1

Flow of participants through the study



Note. HIIT – high-intensity interval training; EDU – educational. [1]Due to: no interest in continuing the programme (*n* = 6); preterm birth (*n* = 1); not feeling well on the day of the second assessment (*n* = 2); did not provide a reason (*n* = 2).

allowing participation in physical activities adapted to pregnant participants (Szumilewicz et al., 2024, p. 2), confirmed by routine obstetric consultation. Exclusion criteria were contraindications to increased physical effort or other conditions that, according to the researchers, could threaten the health or safety of the participants or could significantly affect the quality of the collected data.

PARTICIPANTS

Characteristics of participants are presented in Table 1. Age, body mass index (BMI), physical fitness, and physical activity levels were not statistically significantly different between HIIT and EDU groups. The EDU group was at slightly higher number of weeks of pregnancy. However, we considered the observed statistically significant difference of 4 weeks between groups of no clinical significance. In the pre-intervention assessment, we did not observe any significant differences between groups in any of the measured psychosocial parameters (Table 1).

As additional information, 91% of women from the HIIT group and 90% from the EDU group had a higher educational level. The remaining women had secondary education. 44% of women from the HIIT group and 50% from the EDU group had a mod-

Table 1

Characteristics of study participants

Variable	Group		Statistic[1]	*p*	Effect size[2]
	HIIT n = 34, $M \pm SD$	EDU n = 20, $M \pm SD$			
Age (years)	31.4 ± 4.3	32.2 ± 4.1	$Z = -0.67$	.500	0.092
BMI (height/weight²)	24.4 ± 2.8	25.4 ± 3.2	$t = -1.14$	.259	0.322
Week of gestation	20.3 ± 4.3	23.7 ± 3.8	$t = -2.90$	**.006**	0.816
Initial VO_{2peak} (kg/ml/min)	25.6 ± 4.4	23.7 ± 3.6	$Z = -1.51$	.132	0.205
Initial weekly PA (METs)	2819.8 ± 2298.6	2518.4 ± 2806.2	$Z = -0.88$	.380	0.119

Note. [1]For variables with a distribution close to normal, parametric tests (Student's *t*-test) were used. For variables with a distribution significantly different from normal, non-parametric tests (Mann-Whitney *U* test) were used. [2]For variables with a distribution close to normal, Cohen's *d* was used to evaluate effect sizes. For variables with a distribution significantly different from normal, rank-biserial correlation was used. Bold type indicates a significant difference in the outcome variable.

erate level of physical activity. 38% of women from the HIIT group and 30% from the EDU group reported a high level of physical activity. The remaining 18% of women from the HIIT group and 20% from the EDU group presented a low level of physical activity. The groups did not differ either in their educational level (χ^2 = 0.02, p = .885) or as a category of physical activity measured with the International Physical Activity Questionnaire (IPAQ) (χ^2 = 0.37, p = .829). Of note, a clinical level of depression symptoms was observed in 8.8% (n = 3) of women from the HIIT group and 15% (n = 3) of women in the EDU group at baseline, and in 5.9% (n = 2) of women in the HIIT group and none of the women in the EDU group during the second assessment.

Before (Time 0) and after the intervention (Time 1), we collected data from our study participants using the following tools:

Beck Depression Inventory-II. Depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II; Beck et al., 1996), a widely used self-report measure of depression severity. The instrument consists of 21 items assessing cognitive, affective, and somatic symptoms of depression. Participants rate each item on a 4-point scale ranging from 0 to 3 based on symptom severity experienced during the preceding two weeks. Total scores range from 0 to 63, with higher scores indicating more severe depressive symptoms. Standard cut-off values were applied to classify depression severity: 0-13 (minimal or no depression), 14-19 (mild depression), 20-28 (moderate depression), and 29-63 (severe depression). The BDI-II has demonstrated strong psychometric properties across diverse populations (Beck et al., 1996; Wang & Gorenstein, 2013). In the present study, internal consistency was acceptable, with Cronbach's α values of .78 for the HIIT group and .73 for the EDU group.

Fear of childbirth. Fear of childbirth was measured using the Childbirth Attitudes Questionnaire (CAQ), which was developed based on earlier instruments designed to assess childbirth-related fear (Areskog et al., 1982). The CAQ includes 16 items rated on a 4-point Likert-type scale. Item scores are summed to produce a total score ranging from 16 to 64, with higher scores reflecting greater fear of childbirth. Previous studies have confirmed the questionnaire's reliability and construct validity (Areskog et al., 1982). In the current study, the CAQ demonstrated excellent internal consistency, with Cronbach's α coefficients of .90 in both the HIIT and EDU groups.

Psychological well-being – Flourishing Scale. Psychological well-being was assessed using the Flourishing Scale, an 8-item measure capturing key aspects of optimal psychological functioning, including purpose, competence, self-esteem, and positive relationships (Diener et al., 2010). Responses are provided on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The total score represents an overall indicator of perceived flourishing, with higher values indicating greater psychological well-being. The Flourishing Scale has demonstrated good reliability and validity in previous research (Diener et al., 2010). The results of the analysis indicated that Cronbach's α reached a value of .94 in both the HIIT group and the EDU group, demonstrating a high level of internal consistency in each case. The Polish version of the scale was obtained from the official Ed Diener laboratory resources and has been used in prior Polish samples (Jankowski, 2015).

Health-related quality of life – SF-12. Health-related quality of life was evaluated using the 12-item Short Form Health Survey (SF-12), a widely validated self-administered questionnaire assessing physical and mental health status (Ware et al., 1996). The SF-12 yields two composite indices: the Physical Component Summary (PCS) and the Mental Component Summary (MCS). Items use dichotomous, ordinal, or frequency-based response formats. Higher PCS and

MCS scores indicate better perceived physical and mental health, respectively. The SF-12 has demonstrated high reliability and validity in previous studies (Ware et al., 1996). In the present study, Cronbach's α coefficients were .75 for the HIIT group and .67 for the EDU group.

Stroop Colour–Word Interference Test. Cognitive interference and inhibitory control were assessed using a computerized version of the Stroop Colour–Word Interference Test from Vienna Test System (version S8) (Schuhfried, 2010), based on the classic colour–word interference paradigm developed by Stroop (1935). The task relies on the assumption that reading colour words is a highly automated cognitive process, whereas naming the ink colour requires controlled processing. When the semantic meaning of a word conflicts with its ink colour, interference arises, leading to delayed responses and increased cognitive load.

The task consisted of baseline conditions without interference and interference conditions. Baseline performance was assessed using two conditions: (a) word reading, in which participants read colour words presented in a neutral or uniform ink colour, and (b) colour naming, in which participants named the ink colour of non-semantic stimuli. Reaction times (RTs) obtained in these conditions served as indicators of basic processing speed and individual response tempo, and were used as reference values for subsequent interference indices.

Interference was induced by introducing a mismatch between word meaning and ink colour. In the colour interference condition, reading speed decreased when colour words were printed in incongruent ink colours. In the colour–word interference condition, participants were required to name the ink colour of incongruent colour words, which elicited competition between the automatic reading response and the task-relevant colour-naming response. This condition reliably resulted in prolonged RTs relative to baseline, reflecting the Stroop interference effect.

The primary dependent variables included mean RTs for each condition as well as interference indices, calculated as the difference between RTs in interference conditions and their corresponding baseline conditions. Higher interference scores indicated greater susceptibility to cognitive interference and less efficient inhibitory control. The Stroop task thus provides a robust measure of selective attention, executive functioning, and the ability to suppress dominant but task-irrelevant responses (Hershman et al., 2025).

Moreover, we measured personality traits (TIPI) as well as dispositional optimism (LOT-R). We measured these variables once, before the intervention.

Personality traits – Ten-Item Personality Inventory (TIPI-PL). Personality traits were assessed using the Polish adaptation of the Ten-Item Personality Inventory (TIPI-PL), a brief self-report measure assessing the five dimensions of the Big Five model: extraversion, agreeableness, conscientiousness, emotional stability, and openness to experience (Sorokowska et al., 2014). The TIPI-PL consists of 10 items rated on a 7-point Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*), with each trait measured by two items, one positively and one negatively worded; negatively worded items are reverse-scored, and mean scores are calculated for each trait, with higher values indicating greater expression of the given personality dimension. The Polish version has demonstrated satisfactory psychometric properties, including acceptable reliability for an ultra-brief instrument, high test–retest stability, and good convergent validity with longer personality measures, and is recommended for use in research settings where personality assessment is not the primary focus (Sorokowska et al., 2014).

Dispositional optimism – Life Orientation Test-Revised (LOT-R). Dispositional optimism was assessed using the Polish adaptation of the Life Orientation Test–Revised (LOT-R), a widely used self-report measure of generalized outcome expectancies (Juczyński, 2012; Scheier et al., 1994, 2009). The LOT-R consists of 10 statements rated on a 5-point Likert scale ranging from 0 (*strongly disagree*) to 4 (*strongly agree*), of which six items are diagnostic and four serve as fillers. Three items are positively worded and three negatively worded; negatively formulated items are reverse-scored, and a total optimism score is calculated by summing responses to the six scored items, with higher scores indicating greater dispositional optimism. The Polish version of the LOT-R has demonstrated satisfactory psychometric properties, including acceptable internal consistency, good test–retest reliability, and convergent validity with related constructs such as well-being and mental health indicators, and is recommended for use in both health and psychological research (Juczyński, 2012). In the current study, Cronbach's α was .77 in the HIIT group and .71 in the EDU group.

STATISTICAL ANALYSES

Statistical analyses were performed using IBM SPSS Statistics, version 27.0. Statistical significance was set at $p < .05$. The normality of the distribution of the study variables was assessed using the Kolmogorov-Smirnov test, supported by graphical inspection (Q-Q plots), which yielded results consistent with the K-S test. Inter- and intra-group differences in mean values were analysed using Student's *t*-test. For variables that did not follow a normal distribution, the non-parametric Mann-Whitney *U* test and the Wilcoxon signed-rank test were applied to assess inter- and intra-group differences, respectively. Additionally, the chi-square test was used to evaluate differences in frequencies. The results of the correlation analyses were included in Supplementary materials. Based on the outcomes presented in the correlation matrices, a series of simple linear regressions (enter method) were conducted for variables with a single predictor, as well as a series of multiple regressions (stepwise method) for variables with more than one predictor.

This research was performed according to the principles of the WMA Declaration of Helsinki and with the approval of the Bioethics Commission at the District Medical Chamber in Gdansk (KB-8/21). All participants were asked to sign the informed consent prior to testing. The study protocol was registered at ClinicalTrials.gov (NCT05009433). After trial commencement, no significant methodological changes were introduced. We have followed standards for transparency, openness and reproducibility of research and adhered to the CONSORT standards (Moher et al., 2012).

RESULTS

STROOP TEST PERFORMANCE

For clarity, the text below focuses on the most theoretically relevant outcomes (particularly interference indices), while complete statistical results are presented in the tables.

Between-group comparisons of Stroop test outcomes at baseline (T0) and post-intervention (T1) are presented in Table 2. At baseline, significant group differences were observed for reading interference, with the HIIT group demonstrating lower interference than the EDU group, as reflected by percentile rank and T scores, indicating more efficient inhibitory control. No other baseline differences reached statistical significance.

At post-intervention, the groups did not differ significantly in interference indices for either reading or colour naming. However, significant between-group differences emerged in the reading congruent condition, with the HIIT group showing higher percentile ranks than the EDU group ($p = .028$, $d = .55$), suggesting improved basic processing efficiency. A similar pattern was observed for raw scores in the reading congruent condition ($p = .026$), favouring the HIIT group.

No significant between-group differences were found for incongruent reading, colour naming performance, or error rates in either congruent or incongruent conditions at T1. Total test completion time did not differ significantly between groups at either measurement point. Overall, the results indicate that the HIIT intervention was associated with improvements in selected aspects of reading-related processing efficiency, while interference control and error rates remained comparable between groups.

Within-group changes in Stroop test performance from baseline (T0) to post-intervention (T1) are presented in Table 3. In the HIIT group, significant improvements were observed in several indices of Stroop test performance. Participants showed significant gains in both reading congruent and reading incongruent conditions, as evidenced by increases in raw scores ($p = .002$), percentile ranks ($p = .004$), and T scores ($p = .002$). Similarly, in the incongruent condition, significant increases were found for raw scores ($p = .005$), percentile ranks ($p = .015$), and T scores ($p = .009$), indicating enhanced processing speed and inhibitory control. Significant improvements were also found for colour naming in the congruent condition, with higher percentile ranks and T scores ($p < .05$). Moreover, the HIIT group demonstrated a significant reduction in total errors during the colour naming incongruent condition ($p = .030$), suggesting improved response monitoring under interference conditions. A significant decrease in total Stroop test completion time was also observed ($p < .001$), reflecting improved overall cognitive efficiency. No significant within-group changes were detected for reading interference indices or error rates in the reading congruent condition.

HIIT and cognitive control in pregnancy (RCT)

In the EDU group, significant within-group changes were primarily observed for reading interference indices, with significant improvements in raw scores ($p = .005$), percentile ranks ($p = .009$), and T scores ($p = .005$), indicating reduced susceptibility to interference over time. Additionally, a significant improvement was found for the reading incongruent T score ($p = .001$). The EDU group also exhibited significant reductions in errors during the reading incongruent condition ($p = .010$) and colour naming incongruent condition ($p = .048$). Modest improvements were noted for reading congruent T scores ($p = .042$) and colour naming congruent raw scores ($p = .043$). No significant changes were observed for total Stroop test completion time or colour naming interference indices.

OPTIMISM AND BIG FIVE PERSONALITY TRAITS AS PREDICTORS OF EXECUTIVE FUNCTIONING ASSESSED USING THE STROOP TEST IN THE HIIT AND EDU GROUPS

Prediction analyses were preceded by the calculation of correlation matrices, the description and tabular summary of which are provided in the Supplementary materials.

Both in the HIIT group ($n = 34$) and the EDU group ($n = 20$), a series of simple and multiple linear regression analyses were conducted to examine whether optimism and Big Five personality traits predicted Stroop task performance at pre-test (T0) and post-test (T1). Model fit was evaluated using R^2

Table 2

Between-group comparisons of Stroop test performance at baseline (T0) and post-intervention (T1)

Variable	T0			T1		
	HIIT (*M* ±*SD*), *n* = 34	EDU (*M* ±*SD*), *n* = 20	Between-group difference	HIIT (*M* ±*SD*), *n* = 34	EDU (*M* ±*SD*), *n* = 20	Between-group difference
Reading Interference – Raw score	0.11 ±0.18	0.05 ±0.47	*Z* = −1.93; *p* = .054; *r* = −.26	0.80 ±0.69	0.09 ±0.07	*Z* = −0.35; *p* = .727; *r* = −.05
Reading Interference – Percentile rank (PR)	50.50 ±27.97	67.75 ±25.58	***t* = −2.26; *p* = .014; *d* = .64**	53.68 ±27.41	51.30 ±31.15	*Z* = −0.18; *p* = .857; *r* = −.02
Reading Interference – T score	49.50 ±11.35	55.80 ±8.61	***Z* = −2.35; *p* = .019; *r* = −.31**	60.88 ±55.24	50.25 ±11.00	*Z* = −0.44; *p* = .660; *r* = −.06
Naming Interference – Raw score	0.05 ±0.08	0.03 ±0.02	*Z* = −0.28; *p* = .781; *r* = −.04	0.04 ±0.03	0.03 ±0.02	*t* = 1.39; *p* = .086; *d* = .39
Naming Interference – PR	68.79 ±23.16	72.65 ±17.02	*t* = −0.65; *p* = .260; *d* = .18	65.41 ±19.41	72.50 ±15.35	*Z* = −1.33; *p* = .184; *r* = −.18
Naming Interference – T score	56.50 ±8.47	57.15 ±6.41	*t* = −0.30; *p* = .384; *d* = .08	54.41 ±5.95	56.20 ±4.94	*Z* = −1.38; *p* = .169; *r* = −.19
Reading – Congruent Condition (Raw score)	0.80 ±0.17	0.85 ±0.15	*Z* = −1.61; *p* = .107; *r* = −.22	0.75 ±0.17	0.80 ±0.12	***Z* = −2.23; *p* = .026; *r* = −.30**
Reading – Congruent Condition (PR)	59.09 ±28.46	45.00 ±23.88	***Z* = −1.99; *p* = .047; *r* = −.27**	66.91 ±27.01	52.65 ±23.89	***t* = 1.95; *p* = .028; *d* = .55**
Reading – Congruent Condition (T score)	52.32 ±10.37	48.05 ±7.92	*t* = 1.59; *p* = .059; *d* = .45	55.62 ±11.62	51.10 ±7.97	*t* = 1.54; *p* = .065; *d* = .43
Reading – Incongruent Condition (Raw score)	0.89 ±0.18	0.90 ±0.16	*Z* = −0.67; *p* = .502; *r* = −.09	0.83 ±0.18	0.88 ±0.14	*Z* = −1.72; *p* = .085; *r* = −.23
Reading – Incongruent Condition (PR)	56.21 ±30.35	50.70 ±22.65	*Z* = −0.82; *p* = .410; *r* = −.11	64.44 ±27.61	52.85 ±23.27	*Z* = −1.84; *p* = .066; *r* = −.25
Reading – Incongruent Condition (T score)	51.59 ±10.79	49.55 ±7.61	*Z* = −0.83; *p* = .409; *r* = −.11	54.71 ±10.19	50.40 ±7.29	*Z* = −1.81; *p* = .070; *r* = −.25
Total Errors – Reading Congruent Condition	0.06 ±0.34	0.20 ±0.53	*Z* = −1.58; *p* = .115; *r* = −.22	0.21 ±0.59	0.25 ±0.72	*Z* = −0.06; *p* = .954; *r* = −.01
Total Errors – Reading Incongruent Condition	1.79 ±1.98	1.05 ±1.47	*Z* = −1.66; *p* = .098; *r* = −.23	5.09 ±15.98	2.30 ±3.01	*Z* = −1.27; *p* = .205; *r* = −.17

Table 2 continues

Table 2

Table 2 continued

Variable	T0			T1		
	HIIT (M ±SD), n = 34	EDU (M ±SD), n = 20	Between-group difference	HIIT (M ±SD), n = 34	EDU (M ±SD), n = 20	Between-group difference
Colour Naming – Congruent Condition (Raw score)	0.63 ±0.14	0.68 ±0.09	Z = −1.27; p = .203; r = −.17	0.64 ±0.08	0.66 ±0.08	t = −1.06; p = .147; d = .30
Colour Naming – Congruent Condition (PR)	72.74 ±21.44	68.95 ±22.93	t = 0.61; p = .272; d = .17	78.97 ±17.34	72.40 ±19.09	Z = −1.10; p = .270; r = −.15
Colour Naming – Congruent Condition (T score)	57.79 ±8.37	56.00 ±7.31	t = 0.80; p = .215; d = .22	59.91 ±7.53	57.65 ±7.62	Z = −1.03; p = .305; r = −.14
Colour Naming – Incongruent Condition (Raw score)	0.70 ±0.11	0.71 ±0.09	Z = −0.99; p = .320; r = −.14	0.68 ±0.08	0.69 ±0.07	t = −0.59; p = .280; d = .17
Colour Naming – Incongruent Condition (PR)	76.62 ±19.11	73.60 ±19.06	Z = −0.80; p = .425; r = −.11	80.18 ±14.95	77.60 ±13.41	Z = −0.91; p = .365; r = −.12
Colour Naming – Incongruent Condition (T score)	57.26 ±11.86	57.55 ±6.40	Z = −0.57; p = .566; r = −.08	59.74 ±5.86	58.65 ±5.32	t = 0.68; p = .250; d = .19
Total Errors – Colour Naming Congruent Condition	0.56 ±0.96	0.60 ±0.75	Z = −0.68; p = .498; r = −.09	0.71 ±0.87	0.45 ±0.69	Z = −1.02; p = .309; r = −.14
Total Errors – Colour Naming Incongruent Condition	1.50 ±1.73	1.10 ±1.77	Z = −1.08; p = .278; r = −.15	2.12 ±1.87	1.55 ±1.73	Z = −1.30; p = .193; r = −.18
Total Test Completion Time	3:30:03.53 ± 0:37:13.30	3:35:54.00 ±0:33:14.63	Z = −0.68; p = .496; r = −.09	3:19:54.47 ±0:32:17.87	3:31:27.00 ±0:27:53.73	Z = −1.71; p = .087; r = −.23

Note. For variables with a distribution close to normal, parametric tests (Student's t-test) were used. For variables with a distribution significantly different from normal, non-parametric tests (Mann-Whitney U test) were used, with the Z statistic reported. In order to estimate effect size, we used Cohen's d for testing with Student's t-test and the rank-biserial correlation coefficient (r) for testing with the Mann-Whitney U test. Bold type indicates a significant difference in the outcome variable.

(and adjusted R^2 for multiple regression models), and statistical significance was assessed using F tests and standardized regression coefficients (β). The results are presented in Tables 4 and 5.

HIIT group

Extraversion emerged as a significant predictor of reading interference at post-test. The model explained 12.6% of the variance in reading interference T scores, R^2 = .13, F(1, 32) = 4.61, p = .040, with higher extraversion associated with lower interference (β = −.36).

Openness to experience was a robust predictor of colour naming interference at post-test. Across raw scores, percentile ranks, and T scores, openness accounted for approximately 30% to 33% of the variance in performance (R^2s = .30-.33). All models were statistically significant, with Fs ranging from 13.67 to 15.41 and all ps < .001. Higher openness was consistently associated with lower interference levels (|β|s = .55-.57).

Multiple regression analyses revealed that agreeableness and conscientiousness jointly predicted total errors in the reading congruent condition at pre-test, explaining 19.4% of the variance (adjusted R^2 = .19), F(2, 31) = 4.98, p = .013. Within this model, conscientiousness was the only significant individual predictor, β = −.34, t = −2.08, p = .046. A similar pattern was observed for total errors in the reading incongruent

Table 3

Within-group differences in Stroop test performance from baseline (T0) to post-intervention (T1)

Variable	Group	
	HIIT, *n* = 34	EDU, *n* = 20
Reading Interference – Raw score	$Z = -1.08$; $p = .280$; $r = -.19$	**$t = -2.82$; $p = .005$; $d = .63$**
Reading Interference – Percentile rank (PR)	$t = -0.69$; $p = .247$; $d = .12$	**$Z = -2.62$; $p = .009$; $r = -.59$**
Reading Interference – T score	$Z = -1.49$; $p = .138$; $r = -.26$	**$t = 2.88$; $p = .005$; $d = .16$**
Colour Naming Interference – Raw score	$Z = -0.62$; $p = .538$; $r = -.11$	$t = -0.23$; $p = .409$; $d = .49$
Colour Naming Interference – PR	$Z = -0.44$; $p = .658$; $r = -.08$	$Z = -0.22$; $p = .827$; $r = -.05$
Colour Naming Interference – T score	$Z = -0.93$; $p = .354$; $r = -.16$	$t = 0.61$; $p = .275$; $d = .31$
Reading – Congruen*t* Condition (Raw score)	**$Z = -3.14$; $p = .002$; $r = -.54$**	$Z = -1.48$; $p = .140$; $r = -.33$
Reading – Congruen*t* Condition (PR)	**$Z = -2.01$; $p = .004$; $r = -.34$**	$t = -1.44$; $p = .083$; $d = .32$
Reading – Congruen*t* Condition (T score)	**$t = -3.06$; $p = .002$; $d = .53$**	**$t = -1.82$; $p = .042$; $d = .41$**
Reading – Incongruen*t* Condition (Raw score)	**$Z = -2.83$; $p = .005$; $r = -.49$**	$Z = -0.32$; $p = .751$; $r = -.07$
Reading – Incongruen*t* Condition (PR)	**$Z = -2.43$; $p = .015$; $r = -.42$**	$Z = -0.34$; $p = .737$; $r = -.08$
Reading – Incongruen*t* Condition (T score)	**$Z = -2.60$; $p = .009$; $r = -.45$**	**$Z = -3.216$; $p = .001$; $r = -.719$**
Total Errors – Reading Congruent Condition	$Z = -1.19$; $p = .236$; $r = -.20$	$Z = 0.00$; $p = 1.000$; $r = .00$
Total Errors – Reading Incongruent Condition	$Z = -1.93$; $p = .053$; $r = -.33$	**$Z = -2.58$; $p = .010$; $r = -.58$**
Colour Naming – Congruent Condition (Raw score)	$Z = -1.68$; $p = .092$; $r = -.29$	$t = 1.81$; $p = .043$; $d = .41$
Colour Naming – Congruent Condition (PR)	**$Z = -2.84$; $p = .004$; $r = -.49$**	$t = -1.37$; $p = .093$; $d = .31$
Colour Naming – Congruent Condition (T score)	**$Z = -2.37$; $p = .018$; $r = -.41$**	$t = -1.62$; $p = .060$; $d = .36$
Colour Naming – Incongruent Condition (Raw score)	$Z = -0.90$; $p = .367$; $r = -.16$	$t = 1.61$; $p = .062$; $d = .36$
Colour Naming – Incongruent Condition (PR)	$Z = -1.62$; $p = .105$; $r = -.28$	$t = -1.69$; $p = .053$; $d = .38$
Colour Naming – Incongruent Condition (T score)	$Z = -1.29$; $p = .196$; $r = -.22$	$t = -1.22$; $p = .119$; $d = .27$
Total Errors – Colour Naming Congruent Condition	$Z = -0.88$; $p = .380$; $r = -.15$	$Z = -1.00$; $p = .317$; $r = -.22$
Total Errors – Colour Naming Incongruen*t* Condition	**$Z = -2.18$; $p = .030$; $r = -.37$**	$Z = -1.98$; $p = .048$; $r = -.44$
Total Stroop Test Completion Time	**$Z = -3.45$; $p < .001$; $r = -.59$**	$t = 0.70$; $p = .246$; $d = .16$

Note. For variables with a distribution close to normal, parametric tests (dependent samples Student's *t*-test) were used. For variables with a distribution significantly different from normal, non-parametric tests (Wilcoxon test) were used, with the *Z* statistic reported. In order to estimate effect size, we used Cohen's *d* for testing with Student's *t*-test and the rank-biserial correlation coefficient (*r*) for testing with the Wilcoxon test. Bold type indicates a significant difference in the outcome variable.

Table 4

Linear and multiple regression analyses predicting Stroop test performance from optimism and Big Five personality traits in the HIIT group (n = 34)

Outcome variable (time and metric)	Time	Predictor(s)	R^2/ adj. R^2	F	β	t	p
Reading Interference (T score)	T1	Extraversion	.13	4.61	−.36	−2.15	.040
Colour Naming Interference (Raw, T2)	T1	Openness	.33	15.41	−.57	−3.93	< .001
Colour Naming Interference (PR)	T1	Openness	.30	13.67	.55	3.70	< .001
Colour Naming Interference (T score)	T1	Openness	.31	14.32	.56	3.78	< .001
Total Errors – Reading Congruent	T0	Agreeableness	.19†	4.98	−.27	−1.63	.113
	T0	Conscientiousness			−.34	−2.08	.046
Total Errors – Reading Incongruent	T0	Extraversion	.27†	7.19	−.35	−2.07	.047
	T0	Conscientiousness			−.31	−1.81	.080
Colour Naming Congruent (T score)	T0	Emotional Stability	.16	6.15	−.40	−2.48	.019
Colour Naming Incongruent (PR)	T0	Emotional Stability	.12	4.38	−.35	−2.09	.044
Colour Naming Incongruent (T score)	T0	Emotional Stability	.12	4.24	−.34	−2.06	.048
Total Errors – Colour Naming Congruent	T0	Conscientiousness	.20	7.98	−.45	−2.82	.008
Total Errors – Colour Naming Congruent	T1	Extraversion	.12	4.36	−.35	−2.09	.045
Total Errors – Colour Naming Incongruent	T0	Conscientiousness	.20	7.79	−.44	−2.79	.009
Total Errors – Colour Naming Incongruent	T1	Conscientiousness	.26	10.95	−.51	−3.31	.002

Note. β – standardized regression coefficient; PR – percentile rank; T0 – pre-test; T1 – post-test. †Adjusted R^2 reported for multiple regression models.

condition at pre-test, where extraversion significantly predicted fewer errors, R^2 = .27, adjusted R^2 = .23, $F(2, 31) = 7.19$, $p = .003$, β = −.35, $t = −2.07$, $p = .047$.

Emotional stability significantly predicted colour naming performance at pre-test in both congruent and incongruent conditions. These models explained between 11.7% and 16.1% of the variance (R^2s = .12-.16), with higher emotional stability associated with better performance (βs = −.34 to −.40, all ps < .05).

Conscientiousness consistently predicted fewer total errors in the colour naming task. At pre-test, conscientiousness explained approximately 20% of the variance in total errors for both congruent and incongruent conditions (R^2s = .20), with statistically significant models (Fs ≥ 7.79, ps < .01). At post-test, conscientiousness remained a significant predictor of total errors in the incongruent condition, explaining 25.5% of the variance, R^2 = .26, $F(1, 32) = 10.95$, $p = .002$, β = −.51.

EDU group

Emotional stability emerged as a significant and consistent predictor of reading interference outcomes at post-test. Across raw scores, percentile ranks, and T scores, emotional stability accounted for between 23.5% and 29.6% of the variance (R^2s = .24-.30). All models were statistically significant, with Fs ranging from 5.53 to 7.57 and ps ≤ .030. Higher emotional stability was associated with lower reading interference (|β|s = .49-.54).

Openness to experience significantly predicted colour naming interference at pre-test. The amount of explained variance ranged from 26.1% to 31.1% across raw scores, percentile ranks, and T scores (R^2s = .26-.31). All three models were statistically significant, with Fs between 6.35 and 8.11 and ps ≤ .021. Greater openness was consistently associated with lower interference levels (|β|s = .51-.56).

Table 5

Linear regression analyses predicting Stroop test performance from optimism and Big Five personality traits in the EDU group (n = 20)

Outcome variable (time and metric)	Time	Predictor	R^2	F	β	t	p
Reading Interference (Raw)	T1	Emotional Stability	.24	5.53	–.49	–2.35	.030
Reading Interference (PR)	T1	Emotional Stability	.30	7.57	.54	2.75	.013
Reading Interference (T score)	T1	Emotional Stability	.26	6.47	.51	2.54	.020
Colour Naming Interference (Raw)	T0	Openness	.29	7.31	–.54	–2.70	.015
Colour Naming Interference (PR)	T0	Openness	.31	8.11	.56	2.85	.011
Colour Naming Interference (T score)	T0	Openness	.26	6.35	.51	2.52	.021
Reading Congruent (Raw)	T0	Agreeableness	.20	4.56	.45	2.13	.047
Reading Congruent (PR)	T0	Agreeableness	.26	6.16	–.51	–2.48	.023
Reading Congruent (T score)	T0	Agreeableness	.24	5.82	–.49	–2.41	.027
Total Errors – Reading Incongruent	T1	Agreeableness	.21	4.84	–.46	–2.20	.041
Total Errors – Colour Naming Incongruent	T1	Agreeableness	.29	7.28	–.54	–2.70	.015

Note. β – standardized regression coefficient; PR – percentile rank; T0 – pre-test; T1 – post-test.

Agreeableness emerged as a consistent predictor of reading performance in congruent conditions at pre-test. Across raw scores, percentile ranks, and T scores, agreeableness explained approximately 20.2% to 25.5% of the variance (R^2s = .20-.26), with all models reaching statistical significance (Fs ≥ 4.56, ps ≤ .047).

Additionally, agreeableness significantly predicted total errors in incongruent conditions at post-test. Specifically, agreeableness accounted for 21.2% of the variance in total reading errors, R^2 = .21, F(1, 18) = 4.84, p = .041, and 28.8% of the variance in total colour naming errors, R^2 = .29, F(1, 18) = 7.28, p = .015. In both cases, higher agreeableness was associated with fewer errors (βs = −.46 and −.54, respectively).

PSYCHOLOGICAL VARIABLES (WELL-BEING, MENTAL HEALTH – PHYSICAL AND MENTAL COMPONENTS, DEPRESSION, FEAR OF CHILDBIRTH) AS PREDICTORS OF STROOP PERFORMANCE IN THE HIIT GROUP

To identify psychological predictors of Stroop task performance in both the HIIT group (n = 34) and EDU group (n = 20), a series of regression analyses were conducted. Pre-intervention Stroop outcomes (T0) were predicted exclusively by pre-intervention psychological variables, whereas post-intervention Stroop outcomes (T1) were predicted by psychological variables (well-being, fear of childbirth, physical and mental components of mental health, depression) assessed both before (PRE) and after the intervention (POST). Simple linear regression (enter method) was applied when a single predictor was identified, and multiple regression (stepwise method) was used when more than one predictor emerged. The results are presented in Tables 6 and 7.

HIIT group

Pre-intervention psychological variables were significant predictors of several Stroop indices. Physical well-being (physical component) measured pre-intervention consistently predicted reading-related Stroop performance. Higher physical well-being predicted better performance in the reading congruent condition (percentile rank), R^2 = .15, F(1, 32) = 5.63, p = .024, β = .39, t = 2.37. Similarly, physical well-being predicted outcomes in the reading incongruent condition, including raw scores, R^2 = .16, F(1, 32) = 6.28, p = .018, β = −.41, t = −2.51, percentile rank, R^2 = .19, F(1, 32) = 7.57, p = .010, β = .44, t = 2.75, and T scores, R^2 = .17, F(1, 32) = 6.73, p = .014, β = .42, t = 2.59.

Pre-intervention fear of childbirth was a significant negative predictor of colour naming interference T scores at Time 0, R^2 = .13, F(1, 32) = 4.58, p = .040, β = −.35, t = −2.14, indicating greater interference among women reporting higher childbirth-related fear before the intervention.

Pre-intervention depression emerged as a consistent predictor of colour naming performance. Higher depression predicted poorer outcomes in both congruent and incongruent colour naming condi-

Table 6

Linear regression analyses predicting Stroop performance from psychological variables in the HIIT group (n = 34)

Outcome variable (Stroop)	Time	Predictor (psychological variable)	β	*t*	*p*	R^2	Adjusted R^2	*F*	*p*
Reading Interference (T score)	T1	Physical component (PRE)	–.39	–2.36	.024	.15	–	5.58	.030
Colour Naming Interference (T score)	T0	Fear of childbirth (PRE)	–.35	–2.14	.040	.13	–	4.58	.013
Reading – Congruent (PR)	T0	Physical component (PRE)	.39	2.37	.024	.15	–	5.63	.020
Reading – Incongruent (Raw)	T0	Physical component (PRE)	–.41	–2.51	.018	.16	–	6.28	.015
Reading – Incongruent (PR)	T0	Physical component (PRE)	.44	2.75	.010	.19	–	7.57	.011
Reading – Incongruent (T score)	T0	Physical component (PRE)	.42	2.59	.014	.17	–	6.73	.021
Colour Naming – Congruent (Raw)	T1	Depression (PRE)	–.37	–2.23	.033	.13	–	4.96	.047
Colour Naming – Congruent (PR)	T0	Depression (PRE)	.40	2.46	.019	.16	–	6.07	.047
Colour Naming – Congruent (PR)	T1	Depression (PRE)	.35	2.10	.044	.12	–	4.40	.047
Colour Naming – Congruent (T score)	T0	Depression (PRE)	.41	2.53	.017	.17	–	6.39	.047
Colour Naming – Congruent (T score)	T1	Depression (PRE)	.39	2.39	.023	.15	–	5.69	.047
Colour Naming – Incongruent (Raw)	T0	Depression (PRE)	–.38	–2.32	.027	.14	–	5.40	.047
Colour Naming – Incongruent (PR)	T0	Depression (PRE)	.41	2.52	.017	.17	–	6.36	.047
Colour Naming – Incongruent (T score)	T0	Mental component (PRE)	–.38	–2.31	.028	.14	–	5.32	.047
Errors – Colour Naming Congruent	T0	Physical component (PRE)	.38	2.29	.029	.14	–	5.25	.047
Errors – Colour Naming Incongruent	T0	Physical component (PRE)	.35	2.13	.041	.12	–	4.54	.047
Errors – Colour Naming Incongruent	T0	Depression (PRE)	.38	2.48	.019	–	.24	6.20	.047
	T0	Physical component (PRE)	.41	2.72	.011	–	–	–	.047
Total Stroop Completion Time	T0	Physical component (PRE)	–.34	–2.07	.046	.12	–	4.30	.047
Reading Interference (T score)	T1	Mental component (POST)	–.39	–2.38	.023	.15	–	5.67	.047
Errors – Colour Naming Incongruent	T1	Fear of childbirth (POST)	.37	2.25	.031	.14	–	5.08	.047

Note. β – standardized regression coefficient; PR – percentile rank; PRE – psychological variable measured pre-intervention; POST – psychological variable measured post-intervention. Simple linear regression (enter method) was used for single-predictor models. Stepwise multiple regression was applied when more than one predictor significantly contributed to the model. T0 – pre-intervention Stroop assessment; T1 – post-intervention Stroop assessment.

Table 7

Regression analyses predicting Stroop performance from psychological variables in the EDU group (n = 20)

Outcome variable (Stroop)	Time	Predictor	β	*t*	*p*	R^2	Adjusted R^2	*F*
Errors – Reading Congruent	T1	Depression (PRE)	.42	2.29	.035	–	.45	8.79
		Fear of childbirth (PRE)	.44	2.42	.027	–		
Errors – Reading Incongruent	T0	Physical component (PRE)	.45	2.12	.048	.20	–	4.51
Errors – Reading Incongruent	T1	Physical component (PRE)	.45	2.14	.047	.20	–	4.57
Errors – Colour Naming Congruent	T1	Fear of childbirth (PRE)	.50	2.48	.023	.25	–	6.13
Reading Interference (PR)	T1	Fear of childbirth (POST)	–.52	–2.59	.019	.27	–	6.68
Reading Interference (T score)	T1	Fear of childbirth (POST)	–.45	–2.16	.045	.21	–	4.66

Note. β – standardized regression coefficient; PR – percentile rank; PRE – psychological variable measured pre-intervention; POST – psychological variable measured post-intervention. Simple linear regression (enter method) was used for single-predictor models. Stepwise multiple regression was applied when more than one predictor significantly contributed to the model. T0 – pre-intervention Stroop assessment; T1 – post-intervention Stroop assessment.

tions at Time 1, including congruent percentile rank, R^2 = .16, F(1, 32) = 6.07, p = .019, β = .40, t = 2.46, congruent T scores, R^2 = .17, F(1, 32) = 6.39, p = .017, β = .41, t = 2.53, incongruent raw scores, R^2 = .14, F(1, 32) = 5.40, p = .027, β = –.38, t = –2.32, and incongruent percentile rank, R^2 = .17, F(1, 32) = 6.36, p = .017, β = .41, t = 2.52. Additionally, pre-intervention mental well-being (mental component) significantly predicted colour naming incongruent T scores at Time 1, R^2 = .14, F(1, 32) = 5.32, p = .028, β = –.38, t = –2.31.

Error-related Stroop outcomes were also predicted by pre-intervention physical well-being. Higher physical well-being predicted a greater number of errors in the colour naming congruent condition at Time 1, R^2 = .14, F(1, 32) = 5.25, p = .029, β = .38, t = 2.29, as well as errors in the colour naming incongruent condition, R^2 = .12, F(1, 32) = 4.54, p = .041, β = .35, t = 2.13.

A multiple regression model revealed that post-intervention errors in the colour naming incongruent condition (Time 2) were jointly predicted by pre-intervention depression and physical well-being, adjusted R^2 = .24, F(2, 31) = 6.20, p = .005. Both depression (β = .38, t = 2.48, p = .019) and physical well-being (β = .41, t = 2.72, p = .011) contributed significantly to the model.

Finally, the pre-intervention physical component of mental health predicted total Stroop test completion time at Time 1, R^2 = .12, F(1, 32) = 4.30, p = .046, β = –.34, t = –2.07, indicating faster overall task performance among women reporting better physical health prior to the intervention.

Pre-intervention physical component of mental health also predicted reading interference T scores at Time 1, R^2 = .15, F(1, 32) = 5.58, p = .024, β = –.39, t = –2.36, suggesting a longitudinal effect of baseline physical health on post-intervention inhibitory control.

When considering post-intervention psychological variables only, two significant predictors of post-intervention Stroop performance were identified in the HIIT group. Post-intervention mental component of health significantly predicted reading interference T scores at Time 1, R^2 = .15, F(1, 32) = 5.67, p = .023, β = –.39, t = –2.38, indicating lower interference among women with better post-intervention mental health. Additionally, post-intervention fear of childbirth predicted total errors in the colour naming incongruent condition at Time 1, R^2 = .14, F(1, 32) = 5.08, p = .031, β = .37, t = 2.25, suggesting greater susceptibility to errors under high-interference conditions among women reporting higher levels of childbirth-related fear after the intervention.

EDU group

Pre-intervention psychological variables in the EDU group significantly predicted several error-related Stroop outcomes. A multiple regression model indicated that errors in the reading congruent condition at T1 were jointly predicted by pre-intervention depression and fear of childbirth, adjusted R^2 = .45, F(2, 17) = 8.79, p = .002. Both depression (β = .42, t = 2.29, p = .035) and fear of childbirth (β = .44,

t = 2.42, p = .027) independently contributed to increased error rates.

Pre-intervention well-being (physical component) emerged as a significant predictor of errors in the reading incongruent condition, both at T0, R^2 = .20, $F(1, 18)$ = 4.51, p = .048, β = .45, t = 2.12, and at T1, R^2 = .20, $F(1, 18)$ = 4.57, p = .047, β = .45, t = 2.14, indicating a stable association between higher physical well-being and greater susceptibility to errors under high-interference reading conditions. Additionally, errors in the colour naming congruent condition at T2 were predicted by pre-intervention fear of childbirth, R^2 = .25, $F(1, 18)$ = 6.13, p = .023, β = .50, t = 2.48, suggesting increased error rates among women reporting greater childbirth-related fear prior to the intervention.

When considering post-intervention psychological variables only, fear of childbirth again emerged as a significant predictor of post-intervention Stroop interference in the EDU group. Specifically, higher post-intervention fear of childbirth predicted poorer performance in reading interference percentile rank at T1, R^2 = .27, $F(1, 18)$ = 6.68, p = .019, β = −.52, t = −2.59. A similar effect was observed for reading interference T scores at T1, R^2 = .21, $F(1, 18)$ = 4.66, p = .045, β = −.45, t = −2.16, indicating greater cognitive interference during reading tasks among women with higher levels of childbirth-related fear after the intervention.

DISCUSSION

In psychology, interference refers to a phenomenon in which competing cognitive processes, thoughts, or stimuli disrupt the operation of other processes, resulting in reduced information-processing efficiency and difficulties in maintaining attention. This mechanism serves an important inhibitory function, particularly in situations involving conflict between automatic responses and controlled processes. A classic illustration is the Stroop effect, which demonstrates that automatic processes (e.g., word reading) can substantially impair performance on tasks requiring cognitive control, such as naming the colour of a stimulus (Schuhfried, 2010). During pregnancy, executive functioning may be especially vulnerable to interference due to dynamic hormonal, physiological, and emotional changes, as well as increased psychological load (Barda et al., 2021). In this context, the Stroop task provides a sensitive measure of reading and naming speed, information-processing efficiency, and the degree of response automatization in pregnant women. The analysed indices, including differences between congruent and incongruent conditions, allow for the assessment of susceptibility to interference: positive interference scores indicate increased vulnerability to distraction, whereas negative scores reflect more efficient cognitive control. High susceptibility to interference may be associated with slower work pace and reduced processing efficiency, particularly under elevated emotional stress, whereas very high percentile scores (PR > 84) and shorter median reaction times in congruent conditions, standardized using T scores, characterize women who maintain high executive efficiency even under increased cognitive load.

This randomized trial compared the effects of a prenatal HIIT programme with self-performed MVPA and educational intervention (EDU) on executive functioning indexed by Stroop task performance, and examined whether cognitive outcomes were related to psychological state variables (e.g., depression, fear of childbirth, well-being) and stable traits (Big Five, optimism). Three findings stand out. First, between-group differences at post-test were limited, with the most reliable advantage for HIIT emerging in reading performance under low-conflict conditions (reading congruent). Second, both groups improved over time, but the overall pattern suggests broad within-group gains in both conditions, with selective advantages for HIIT in reading-related processing efficiency, whereas interference control and accuracy were largely comparable between groups at post-test. Third, individual differences mattered: personality traits and pregnancy-relevant psychological variables predicted Stroop indices in both groups, implying that cognitive responses to prenatal interventions may be partly contingent on affective state and dispositional characteristics.

COGNITIVE OUTCOMES

Analysis of between-group differences revealed a selective advantage of HIIT in reading efficiency. At baseline, the groups differed in reading interference indices (percentile rank and T score), with the HIIT group demonstrating more efficient inhibitory control prior to the intervention. This baseline imbalance is important, as it may have partially constrained the interpretation of post-intervention contrasts by limiting the potential for additional detectable improvement (i.e., ceiling or restricted-change effects). On the other hand, this result may be interpreted as reflecting the sustained effectiveness of inhibitory control in the HIIT group. Following the intervention, between-group differences in interference indices were no longer observed, indicating a convergence of performance over time. From a mechanistic, broad perspective, HIIT may exert its most immediate cognitive effects through pathways that enhance global processing efficiency such as arousal regulation, catecholaminergic modulation, and improved cardiovascular responsiveness, which are more readily expressed in lower-conflict conditions (Sudo et al., 2022; Yue et al., 2025). In contrast, interference control relies on additional top-down mechanisms (e.g., conflict monitoring, inhibitory gating, response selection) that may be less sensitive to short-term training or may improve similarly in both groups due to shared intervention components, including behavioural activation, regular physical activity, structured routines, expectancy effects, and repeated cognitive engagement (Botvinick et al., 2001). Consequently, the absence of post-test between-group differences in interference indices does not indicate a lack of intervention effects but rather suggests that both conditions adequately supported interference-related outcomes, while HIIT conferred a more specific benefit in reading efficiency. This cautious interpretation is also in line with prospective pregnancy research suggesting that objectively measured cognitive changes during pregnancy are often subtle and not uniformly expressed across domains or study designs (Christensen et al., 2010).

Analysis of within-group change indicated that both interventions were associated with improvement, albeit in different cognitive domains. Within-group analyses showed that the HIIT group demonstrated improvements across multiple indices, including reading performance in both congruent and incongruent conditions (raw scores, percentile ranks, and T scores), enhanced colour naming performance in the congruent condition (percentile ranks and T scores), fewer errors in the colour naming incongruent condition, and a markedly faster total task completion time. Collectively, this constellation suggests a broad enhancement of cognitive efficiency and response monitoring, with particular gains in overall speed and in accuracy under higher interference for colour naming. On the other hand, in the EDU group, improvements were most consistent for reading interference indices (raw, percentile rank, T score), along with an increase in reading incongruent T scores and reductions in errors in both reading incongruent and colour naming incongruent conditions. This pattern suggests that MVPA may have supported interference reduction and accuracy, outcomes that are plausibly shaped by lower stress reactivity, improved coping resources, and greater familiarity and confidence with task demands. More broadly, acute stress reliably alters executive-control performance (including inhibition-related components) and can change how efficiently people resolve competing information, consistent with the idea that reducing stress-related load can "clean up" performance in interference tasks (Shields et al., 2016). In line with this interpretation, work using Stroop variants shows that state anxiety and affective dimensions can meaningfully influence interference patterns, implying that improvements in affective state (e.g., less worry/uncertainty) may translate into better interference indices without necessarily producing large global speeding effects (Lago et al., 2022).

Taken together, these results are consistent with a domain-specific "signature": HIIT appears more strongly associated with gains in processing efficiency and global speed, whereas MVPA-related improvements were most evident in interference reduction and error decreases in high-conflict conditions. Importantly, the lack of post-test between-group differences in many indices suggests that both interventions may be beneficial, albeit via partially different cognitive pathways. This domain-specific pattern is consistent with pregnancy-focused evidence indicating that cognitive changes during pregnancy are selective rather than generalized, with reductions observed particularly in processing speed and cognitive flexibility (Rehbein et al., 2022).

PSYCHOLOGICAL PREDICTORS

When examining personality profiles as predictors of executive functioning, their associations with Stroop task performance differed depending on the measurement occasion (pre- vs. post-intervention) and the cognitive domain assessed. Regression models indicated that personality traits predicted Stroop outcomes, but with different patterns across HIIT and EDU. In the HIIT group, extraversion predicted lower post-test reading interference, and openness robustly predicted post-test colour naming interference across metrics. Conscientiousness predicted fewer errors in colour naming at both baseline and post-test, and emotional stability predicted baseline colour naming performance. This pattern is theoretically coherent and aligns with established personality–cognition frameworks. Conscientiousness has been repeatedly linked to stronger self-regulatory capacity, goal maintenance, and error monitoring, processes that support careful performance and reduced error rates under demanding task conditions (e.g., attentional control and performance monitoring; Eisenberg et al., 2014; Jackson et al., 2010). Openness to experience, in turn, has been associated with greater cognitive flexibility, exploratory information processing, and adaptive strategy shifting, all of which may facilitate more efficient resolution of competing stimulus dimensions in interference contexts (DeYoung et al., 2005; Kaufman et al., 2016). Finally, extraversion is commonly linked to approach-related activation, positive affect, and heightened reward sensitivity, which may promote faster response initiation and efficient performance in time-pressured tasks, particularly when accuracy demands are moderate rather than maximal (Matthews & Gilliland, 1999; Smillie et al., 2012).

In the EDU group, emotional stability predicted post-test reading interference outcomes, and agreeableness predicted multiple reading congruent indices at baseline as well as fewer errors in incongruent conditions at post-test. The role of emotional stability in the EDU intervention is theoretically and empirically plausible given its content and testing context. Emotional stability (low neuroticism) has been consistently associated with reduced stress reactivity, more efficient attentional control, and lower susceptibility to anxiety-related cognitive interference, all of which are known to influence performance on conflict-based tasks such as the Stroop (Eysenck et al., 2007; Wilkowski et al., 2010). EDU group individuals higher in emotional stability may therefore have experienced less affective and physiological disruption during testing and may have benefited more from the educational context and self-performed MVPA, translating into improved interference control. Agreeableness, in turn, has been linked to cooperative task engagement, compliance with instructions, and greater responsiveness to structured guidance, particularly in intervention or educational contexts (Graziano & Tobin, 2009; Hill et al., 2011), which may promote a more careful, accuracy-oriented task approach and fewer errors under high-conflict (incongruent) conditions at post-test.

Taken together, these findings suggest that intervention effects were not uniform across participants, but rather interacted with stable dispositional characteristics, highlighting the relevance of individual-differences frameworks in explaining cognitive outcomes. This aligns with broader evidence indicating that personality traits can moderate responsiveness to behavioural, educational, and stress-related interventions, and underscores the value of incorporating personality-informed approaches in prenatal cognitive and psychosocial research (Bogg & Roberts, 2013; Mõttus et al., 2020).

Analyses of psychological state variables as predictors indicated that fear of childbirth and depressive symptoms were systematically associated with accuracy and interference-related outcomes. Across correlation and regression analyses, psychological variables, particularly fear of childbirth and depressive symptoms, were repeatedly linked to Stroop task accuracy and interference indices, although the strength and direction of these associations varied by group and assessment timing, which is consistent with pregnancy-specific evidence indicating that pregnancy-related anxiety and depressive symptoms are associated with greater errors in executive and working-memory performance during pregnancy (Kataja et al., 2017). In the HIIT group, baseline physical and mental components of health predicted several reading-related outcomes and post-intervention reading interference, whereas baseline depressive symptoms consistently predicted colour-naming performance and, in combination with the physical and mental components of health, post-intervention errors in the incongruent colour-naming condition. At post-intervention, better mental health was associated with lower reading interference, while greater fear of childbirth predicted increased error rates under high-interference conditions. Importantly, these results align with our previous findings demonstrating that prenatal HIIT improves or stabilizes key indicators of mental health, including depressive symptoms, psychological well-being, and fear of childbirth, without adverse stress-related consequences. As shown in our earlier randomized trials, both HIIT and EDU interventions reduced depressive symptoms and childbirth-related fears, while HIIT additionally supported mental well-being and adaptive stress responses, even in the presence of increased physiological activation indexed by cortisol (Wilczyńska et al., 2024). Taken together, the present findings suggest that even when HIIT-related cognitive benefits are observed, emotional and health-related factors continue to meaningfully shape executive performance, particularly accuracy under high-interference conditions. Notably, by improving mental health during pregnancy, as demonstrated in our earlier work, HIIT may indirectly create a more favourable affective context for cognitive functioning (Wilczyńska et al., 2022).

In the EDU group, psychological predictors were concentrated in error outcomes and reading interference at post-test. Pre-intervention depression and fear of childbirth jointly predicted errors in the reading congruent condition after the intervention, while post-intervention fear of childbirth predicted poorer reading interference indices measured after the intervention. This pattern converges with evidence that worry- and depression-related processes consume executive resources, thereby impairing attentional filtering and conflict resolution, effects that are especially pronounced in incongruent or cognitively demanding conditions (Eysenck et al., 2007; Owens et al., 2012). The repeated emergence of fear of childbirth, even after intervention, suggests that pregnancy-specific concerns represent a particularly salient source of cognitive load during late pregnancy. This interpretation is strongly supported by our prior studies showing that fear of childbirth is both prevalent and modifiable through prenatal interventions (Wilczyńska et al., 2022, 2024), yet remains a robust psychological determinant with functional consequences when elevated. Accordingly, fear of childbirth should be considered not only as a key outcome of prenatal interventions, but also as a predictor of cognitive performance and responsiveness, reinforcing the importance of integrating psychological screening and affect-focused components into prenatal activity-based programmes.

PRACTICAL IMPLICATIONS

From a clinical and applied perspective, the results suggest that prenatal HIIT may support processing efficiency (especially reading-related speed under low conflict) and broader cognitive efficiency (as indexed by reduced completion time), whereas self-performed MVPA and lifestyle education may support interference reduction and accuracy in high-conflict conditions. Importantly, psychological factors, particularly fear of childbirth and depressive symptoms, were associated with performance and predicted outcomes in both groups, indicating that integrating psychological screening and targeted support (e.g., brief CBT-informed strategies for fear of childbirth, stress management) may enhance cognitive and broader functional benefits of prenatal programmes. The trait findings further imply that tailoring or stratifying interventions based on dispositional profiles (e.g., conscientiousness, emotional stability) may help optimize outcomes.

LIMITATIONS AND FUTURE DIRECTIONS

Interpretation of the results warrants consideration of several limitations. First, baseline between-group differences in reading interference indicate imperfect equivalence before interventions, which may bias post-test comparisons and reduce interpretability of "change" without models controlling for baseline; in the present study, baseline values were included in regression analyses, although future studies may benefit from more explicit covariate approaches to further strengthen causal inference. Secondly, Stroop improvements of the cognitive functioning may partially reflect practice effects; designs with alternate forms or additional executive tasks would help isolate intervention-specific effects.

Moreover, the absence of clear between-group differences at post-test should be interpreted with caution, as it may reflect limited statistical power, sample size constraints, or the sensitivity of the cognitive measures applied. At the same time, observed within-group improvements and associations with psychological variables may still be of potential practical relevance, even in the absence of strong between-group effects. Finally, future studies should examine the moderating roles of psychological and personality factors, and incorporate objective indicators of fitness and training exposure to clarify the mechanisms linking HIIT to cognitive efficiency.

CONCLUSIONS

Overall, the findings indicate that both HIIT and EDU interventions were associated with improvements in executive functioning during pregnancy, but with different emphases: HIIT was linked to broader gains in reading-related efficiency and overall task speed, whereas EDU intervention showed clearer improvements in reading interference and some high-conflict error reductions. Psychological factors, particularly fear of childbirth and depressive symptoms, and stable traits were meaningfully related to Stroop outcomes, underscoring the importance of considering individual differences when interpreting cognitive responses to prenatal interventions.

Supplementary materials are available on the journal's website.

Disclosures

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The authors declare no conflict of interest.

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