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Empowering moms: Supervised HIIT vs. self-performed moderate intensity physical activity during pregnancy and the battle against depression and poor mental health in the postpartum period - The follow-up of a randomized controlled trial

Tamara Walczak-Kozłowska[1] | **Dominika Wilczyńska**[2] | **Rita Santos-Rocha**[3,4] | **Anna Szumilewicz**[5]

[1]Department of Neuropsychology, Institute of Psychology, University of Gdansk, Poland

[2]Faculty of Social and Humanities, WSB Merito University in Gdansk, Poland

[3]ESDRM Sport Sciences School of Rio Maior, Santarém Polytechnic University, Rio Maior, Portugal

[4]SPRINT Sport Physical Activity and Health Research & Innovation Center, Rio Maior, Portugal

[5]Department of Physical Culture, Gdansk University of Physical Education and Sport, Poland

Correspondence
Dominika Wilczyńska, Faculty of Social and Humanities, WSB Merito University in Gdansk Poland.
Email: dominika.wilczynska@gdansk.merito.pl

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Abstract

This study assessed the impact of prenatal High-Intensity Interval Training (HIIT) and educational (EDU) interventions on depression symptoms, psychological well-being, and health among postpartum women. Fifty-three Caucasian women in uncomplicated singleton pregnancies were divided into HIIT (n = 34) and EDU (n = 19) groups. Depression symptoms were measured using the Beck Depression Inventory and Edinburgh Postnatal Depression Scale. Psychological well-being and mental and physical health were assessed using the Flourishing Scale and SF-12 at three time points: before and after an 8-week intervention during pregnancy, and five months postpartum. There were no between-group differences in all three assessments, both in the severity of depression symptoms, psychological well-being, as well as physical and mental health. Both groups showed an increase in postpartum scores for depressive symptoms, although mean scores were still relatively low. A postpartum decline in well-being and mental health indicators was

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significant only in the EDU group. Both interventions had similar effects on depressive symptoms and well-being. Prenatal HIIT may have the potential to maintain postpartum mental health, but this requires further exploration.

KEYWORDS

high-intensity interval training, maternal exercise, postpartum depression, pregnancy, prenatal training

INTRODUCTION

Both pregnancy and postpartum represent a critical juncture in a woman's life, characterized by hormonal fluctuations, physical changes, and profound adjustments in lifestyle and responsibilities (Mehta & Kling, 2020). Although there's agreement that the postpartum period commences at the birth of the newborn, there is less consensus regarding its termination. Evenson et al. (2023) suggest four phases of the postpartum period: acute postpartum (up to 24 hours after birth), early postpartum (from day 2 to 6–8 weeks postpartum), mid-postpartum (6–8 weeks to 6 months postpartum), and late postpartum (up to 12 months, longer if the mother is still breastfeeding). While the postpartum period can indeed be characterized by moments of happiness and anticipation, it can also evoke feelings of vulnerability and stress (Hu et al., 2024), thereby predisposing women to *baby blues* in early postpartum (experienced by approx. 80% of postpartum women, see Can, 2013; Maliszewska et al., 2017) or even mental health disorders such as postpartum depression (PPD, experienced by approx. 13–20% of women in highly developed countries, mostly in early and mid-postpartum periods, see O'Hara & Swain, 1996; Maliszewska et al., 2017) or postpartum psychosis (affecting approx. 0.89–2.6% of women in early postpartum period, see VanderKriuk et al., 2017).

Postpartum depression

Although *baby blues* affects a very high percentage of women, its characteristic feature is that it appears quickly (within the first 14 days after giving birth) and passes quickly, usually spontaneously, although social support and understanding are important (Chrzan-Dętkoś & Murawska, 2023). Much more attention requires postpartum depression, which manifests as a depressive episode following childbirth (typically emerging 2–3 weeks post-delivery, however in some cases, diagnosis may not occur until 4–5 months postpartum), marked by a persistent low mood and diminished interest or enjoyment in usual activities (American Psychiatric Association, 2013; World Health Organization, 2004). Episodes generally persist for 3 to 9 months, though they can occasionally extend to 12 months (American Psychiatric Association, 2013). In PPD, mothers frequently experience overwhelming guilt, believing they are inadequate caregivers and viewing themselves as unfit mothers. Alongside this, they often struggle with profound fatigue, hindering their ability to carry out essential tasks. Furthermore, suicidal thoughts and inclinations may also be present (Janik et al., 2018). Additionally, women may experience panic attacks, anxiety disorders, and both excessive and inadequate concern for

their own and their baby's health. Intrusive thoughts about causing harm to the baby may also occur (Patel et al., 2012). Worth noting is the fact that ∼50% of the impacted mothers go unnoticed by healthcare professionals (Ellis et al., 2016). This issue is profoundly serious, affecting not only mothers but also their children and the entire family system (Letourneau et al., 2012). PPD represents a significant mental health concern globally, disrupting the crucial bond between mother and infant and potentially leading to detrimental effects on the child's long-term cognitive, behavioral, and social–emotional development (Altuntuğ et al., 2018). Drug treatment during pregnancy and postpartum (when the mother is breastfeeding) is difficult due to side effects for the mother and her child. Therefore, women often look for alternative methods already during pregnancy that could help them maintain their well-being and mental health after childbirth, to reduce the risk of postpartum mental disorders.

Enhancement of postpartum mental health through physical activity during pregnancy

Prenatal physical activity (PA) enhances postpartum mental health by reducing anxiety, depressive symptoms, and pain while improving psychological well-being (Davenport, 2020; Guszkowska, 2014), though many women face barriers to resuming PA postpartum due to recovery needs (Santos-Rocha & Szumilewicz, 2022) or lack of knowledge on safe exercise (Krans et al., 2005). Studies show that PA may lower postpartum depression risk (Songøygard et al., 2012; Yuan et al., 2022), but the effects of high-intensity exercise remain underexplored and still are not well understood (Evenson et al., 2014). However, in our previous studies, we demonstrated that High-Intensity Interval Training (HIIT) during pregnancy not only enhances mental well-being but also helps maintain cardiorespiratory fitness, potentially facilitating a smoother transition to postpartum PA (Wilczyńska et al., 2022, 2023). Importantly, these studies were conducted in the same cohort of pregnant women examined in the current manuscript. In our first article, which is part of a broader project on the effectiveness of a HIIT program for pregnant and postpartum participants, we assessed the effects of an 8-week supervised online HIIT program on depressive symptoms, fear of childbirth, fear of COVID-19, and overall quality of life in 54 pregnant women. Both the HIIT and the education-based moderate-intensity PA group (EDU) showed a positive tendency for the decline in the severity of depressive symptoms, fear of childbirth, and fear of COVID-19. Additionally, whereas the EDU group exhibited a decline in cardiorespiratory fitness, the HIIT group maintained their fitness levels, reinforcing the broader mental and physical health benefits of HIIT during pregnancy (Wilczyńska et al., 2023). In our second work, we examined the relation between HIIT, cortisol levels, and psychological well-being in pregnant women. Among 38 participants, those in the HIIT group exhibited an increase in hair cortisol levels, while the education-based moderate-intensity PA group (EDU) showed a decrease. Importantly, this rise in cortisol did not correlate with negative psychological outcomes—fear of childbirth, depressive symptoms, and psychophysical health remained stable. Instead, only the HIIT group experienced a significant improvement in mental well-being, suggesting that increased cortisol may reflect an adaptive (eustress) rather than harmful stress (dystress) response (Wilczyńska et al., 2022). This result confirms the observations from the review and meta-analysis of Dote-Montero et al. (2021) that cortisol levels increase immediately after a single HIIT session and subsequently drop below baseline levels, and ultimately return to baseline values after 24 h. The deeper explanation is that the bouts of intense exercise triggers a physiological stress response affecting multiple body systems

(endocrine, muscular, respiratory, cardiovascular). The hypothalamic–pituitary–adrenal (HPA) axis responds by releasing corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to produce adrenocorticotropin hormone (ACTH). ACTH then regulates adrenal function, leading to cortisol release. This shift from anabolic toward catabolic processes is beneficial for body adaptation in the short term.

These two works of ours are exceptional in how they describe and analyze the implementation of HIIT among pregnant women, highlighting it as a promising intervention that offers both psychological and physiological benefits. By enhancing mental well-being and maintaining fitness levels, HIIT may help mitigate postpartum mental health challenges and support long-term maternal health. There are other studies that suggest that the physical and mental well-being of pregnant women, particularly their engagement in PA, may play a role in the onset and severity of postpartum depression (PPD) (Davenport et al., 2018; Lewis & Kennedy, 2011). Also, the meta-analysis of Yuan et al. (2022) identified PA as a potential intervention to reduce the risk of PPD.

Aim of the study

The studies that focus on the influence of intensive and interval forms of PA on PPD are a very unexplored field. Our past two studies on pregnant women suggest that HIIT intervention provides mental health benefits and might offer additional advantages in maintaining physical fitness and managing stress hormones, which could be crucial during pregnancy (Wilczyńska et al., 2022, 2023). However, we believe it is important to consider the durability of the observed effects of HIIT trainings during pregnancy on women's mental health in the postpartum period. Especially since it often takes women longer to return to PA, and many of them do not return to it for a very long time (Evenson et al., 2014). Therefore, in this study, we aimed to explore the long-term impacts of an 8-week supervised online HIIT intervention on postpartum recovery and mental health, and to explore the intricate connections between PA levels during pregnancy and the physical and mental health outcomes of postpartum mothers (including severity of postpartum depression symptoms).

METHODS

A group of 53 Caucasian women in uncomplicated, singleton pregnancy (age 32 ± 4 years, 22 ± 4 weeks of gestation; mean ± SD) who voluntarily responded to our mass media invitation were eligible to participate in this randomized control trial. Participants were randomly allocated into either the High Intensity Interval Training group (HIIT group) or the educational intervention group (EDU group) using the pipeline arm-focused randomization (PAFR) model, based on the assumptions of pipeline randomization (White, 2013) or stepped wedge randomization, to avoid the 'contamination effect', feasibility, and ethical issues during the study implementation (Cook et al., 2016). The allocation ratio was 1:1. The eligibility criterion was a normal course of pregnancy, confirmed by the routine obstetric consultation. Among the exclusion criteria were contraindications to PA during pregnancy (Szumilewicz et al., 2024) or other conditions that could threaten the health or safety of the participants or significantly affect the quality of the collected data. The flow of the participants through the study is presented in Figure 1.

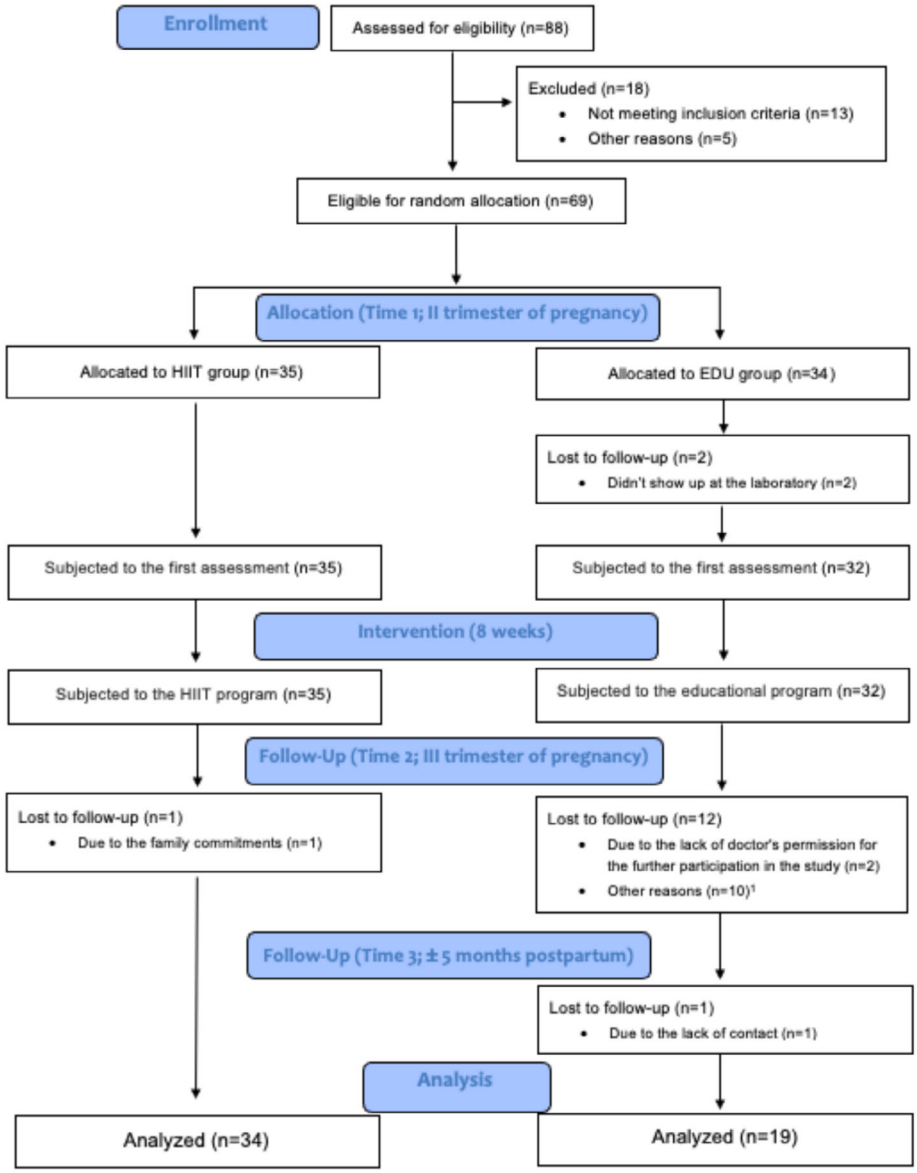

FIGURE 1 Flow of participants through the study. Note. HIIT – high-intensity interval training; EDU – educational intervention. [1] Other reasons: no interest to continue the program (n = 4); preterm birth (n = 1); taking medications which could influence the outcomes of the study (n = 1); not feeling well on the day of the second assessment (n = 2); did not provide the reason (n = 2).

The first two stages of the data collection (Time 1 and Time 2) were conducted in [*blinded*] in Gdansk, Poland, in 2021. The first assessment took place before the intervention, an 8-week high-intensity interval training program for the HIIT group, and an 8-week educational program on a healthy lifestyle and PA in the perinatal period for the EDU group. The second assessment was provided immediately after the interventions. In these first two stages, all women were in their second and third trimesters of pregnancy. In the last stage of the study (Time 3), women completed online questionnaires approximately 5 months (+/− 1 month) after giving birth.

Participants

There were 34 participants in the experimental group, who participated in an 8-week high-intensity interval training program (HIIT group). The comparative group consisted of 19 pregnant participants who attended 8-week educational program on a healthy lifestyle and PA in the perinatal period (EDU group). We used the G*power (version 3.1.3.) software in order to predetermine sample size. The minimal sample size of 32 (16 for each group) with an allocation ratio 1:1, a power of 0.9, and an alpha of 0.05 was predetermined based on the values of the mean and SD from preliminary tests with eight women from the HIIT group and eight women from the EDU group.

The characteristics of study participants are presented in Table 1. Groups did not differ in terms of age, body mass index (BMI), initial maximal oxygen consumption (VO_{2max}), initial weekly PA in metabolic equivalents (METs), depressive symptoms, physical and mental health; however, they differed significantly in week of gestation at baseline. Despite the difference in this aspect, all participants were in the second trimester of pregnancy, therefore, we assumed that the observed statistical difference regarding the week of pregnancy has no clinical significance for the further analyzed differences between groups.

Of note, groups did not differ in postpartum weekly PA (METs) as well as postpartum category of PA ($X^2 = 12.873$, $p = .002$; see Table 1). Therefore, we can assume that the observed effects related to mental health and depressive symptoms were determined by the PA interventions during pregnancy. Based on the outcomes of International Physical Activity

TABLE 1 The characteristics of the study participants.

Variable	Group				
	HIIT n = 34, $M \pm SD$	EDU n = 19, $M \pm SD$	Statistics[1]	p-value	Effect size[2]
Age (years)	31.35 ± 4.25	32.26 ± 4.21	$t = -.750$	.457	$d = .215$
BMI (height/weight²)	24.44 ± 2.75	25.53 ± 3.19	$t = -1.312$	.196	$d = .376$
Week of gestation	**20.32 ± 4.29**	**23.68 ± 3.77**	$\boldsymbol{Z = -2.709}$	**.007**	$\boldsymbol{r = .372}$
Initial VO_{2max} (kg/ml/min)	25.59 ± 4.37	23.73 ± 3.67	$Z = -1.403$	.161	$r = .196$
Initial weekly PA (METs)	2819.79 ± 2298.56	2595.53 ± 2861.27	$Z = -.742$	.458	$r = .102$
Depressive symptoms (BDI-II score)	5.68 ± 4.44	5.47 ± 3.75	$t = .168$	.867	$d = .048$
Physical health (PCS score)	48.45 ± 6.98	46.54 ± 6.51	$t = .979$	.332	$d = .280$
Mental health (MCS score)	48.46 ± 7.23	52.03 ± 6.51	$t = -1.785$	.080	$d = .511$
Postpartum weekly PA (METs)	3478.91 ± 1984.29	2841.63 ± 1412.41	$Z = -1.206$	.228	$r = .169$

[1]In case of variables with a distribution close to normal distribution, we used parametric testing with Student t test, and in case of variables with a distribution significantly different from the normal distribution, we used non-parametric testing with Mann–Whitney *U* test.

[2]In order to estimate effect size, we used Cohen's *d* for testing with Student t test and rank-biserial correlation coefficient (*r*) for testing with Mann–Whitney *U* test.

Questionnaire (IPAQ) most women were those whose postpartum PA category could be described as "high" (HIIT: 53%, EDU: 47%); fewer whose PA could be described as "moderate" (HIIT: 32%, EDU: 32%); and the fewest with "low" PA (HIIT: 15%, EDU: 21%). As postpartum PA, we considered full-body physical exercises, which could include low-intensity exercises performed in bed. Additionally, in the HIIT group, most women indicated that they return to PA "after couple days" (32.4%), an identical percentage of women indicated the answers "after a few hours" (26.5%), and "after a few weeks" (26.5%). Only 14.7% of women indicated that they "did not return to PA after giving birth.". In the EDU group most women indicated that they return to PA "after a few weeks" (47.4%), 36.8% pointed that they return to PA "after couple days", and 15.5% indicated that they "did not return to physical activity after giving birth.".

Bold type indicates a significant difference in the outcome variable.

All participating women were assessed with the following tools before (Time 1), after the intervention (Time 2), and during postpartum follow-up (Time 3), apart from the Edinburgh Postnatal Depression Scale, which was used only in the postpartum period.

Beck depression inventory – II (BDI-II)

To evaluate the presence and severity of depression symptoms, we utilized the Beck Depression Inventory – II (BDI-II), polish adaptation by Łojek and Stańczak (2019). This self-reported inventory consists of 21 items, each rated by participants on a Likert scale from 0 to 3 (e.g., As I look back on my life, all I can see is a lot of failures), reflecting the intensity of depressive symptoms experienced over the past two weeks. Scores range from 0 to 63, with clinical cutoff points as follows: 0–13 indicating no depression, 14–19 indicating mild depression, 20–28 indicating moderate depression, and 29–63 indicating severe depression. The BDI-II is known for its reliable psychometric properties (Beck et al., 1996). In our study, the Cronbach's alpha for the BDI-II assessment was 0.78 for the HIIT group and 0.73 for the EDU group.

The flourishing scale

The Flourishing Scale is composed of eight items that together provide a single psychological well-being score. Each item is rated on a seven-point Likert scale (one-strongly disagree to seven-strongly agree) (e.g., I am competent and capable in the activities that are important to me). The higher the total score, the greater the level of perceived flourishing (Diener et al., 2010). The Polish translation of the scale is available on Ed Diener website: https://labs.psychology.illinois.edu/~ediener/FS.html.

12-item short form health survey (SF-12)

Health-related quality of life was assessed using the 12-item Short Form Health Survey (SF-12) questionnaire, which includes physical (PCS) and mental (MCS) subscales, polish adaptation by Ware (2005). This self-administered questionnaire evaluates both physical and mental health status. Responses are varied, including dichotomous (yes/no) (e.g., Does your health now limit you in moderate activities such as moving table, pushing a vacuum cleaner?), ordinal

(excellent to poor) (e.g., In general would you say your health is ...), and frequency-based (always to never) formats (e.g., During the past 4 weeks have you felt calm and peaceful?). The scores obtained from the SF-12 allow for the calculation of Physical Component Summary (PCS) and Mental Component Summary (MCS) scores, where higher scores indicate better health status. According to Ware et al. (1996), the SF-12 demonstrates a reliability with a Cronbach's alpha of 0.93. In our study, the Cronbach's alpha for the HIIT group was 0.75, and for the EDU group it was 0.67.

The Edinburgh postnatal depression scale

In order to detect the severity of the PPD symptoms in women, the Edinburgh Postnatal Depression Scale (EPDS) by Cox et al. (1987) was used in this study, polish adaptation by Kossakowska (2013). This short (10-item), self-reporting survey is recommended as a screening tool when used by medical personnel who do not directly provide psychological/psychiatric services. Each item is rated by participants on a Likert scale from 0 to 3 (e.g., I have felt happy most of the time during the past week),. Scores in the EPDS range from 0 to 30 and are commonly interpreted regarding two cut-off points:

- 10–11 points: slightly increased severity of PPD symptoms,
- 12 or more points: increased severity of PPD symptoms (requiring extended clinical assessment).

International physical activity questionnaire

PA levels were assessed using the short form of the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003). This questionnaire, known for its acceptable measurement properties, reports weekly PA levels in terms of multiples of the resting metabolic rate (METs) (e.g., During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?). Based on the IPAQ results, we classified the pregnant participants into three PA categories: low (inactive), moderate (meeting the minimum recommended level of activity), and high (exceeding the minimum recommended level of activity) (Cheng, 2016; IPAQ, 2005).

Experimental training and educational interventions

The HIIT program involved three 60-minute training sessions per week for a duration of eight weeks. It was developed in line with available evidence on HIIT during pregnancy (Szumilewicz et al., 2022). Each session began with a warm-up, including a brief instructional guide on performing the exercises in the main part (lasting about 7–10 minutes). The main part of the session, lasting around 15–20 minutes, was conducted as high-intensity intervals. After the interval part of the training, participants performed resistance, postural, neuromotor (e.g., body balance), and stretching exercises, which lasted approx. 5–10 min. The cool-down part consisted of pelvic floor muscle exercises and preparation-for-birth exercises, e.g., birth position and breathing exercises (5–10 min) as well as relaxation and visualization of

pregnancy and childbirth (5–15 min). This exercise program was tailored to the individual requirements and capacities of the pregnant women based on diagnostic exercise test results. It was offered to pregnant women regardless of their fitness level, athletic ability, or motor skills. Each participant's individual heart rate at the anaerobic threshold (HR/AT) was determined through a progressive maximal exercise test, averaging 88 ± 5% of their maximum heart rate. Participants were instructed to exceed their HR/AT during the workout intervals, using a heart rate monitor (Polar RS400, Finland). Each participant received her own heart rate monitor as part of her participation in the study to assess the intensity in each HIIT session. Additionally, we monitored the exercise intensity with the use of the 0–10 Borg Rating of Perceived Exertion (RPE) (Borg, 1998) and the Talk Test (Persinger et al., 2004). The HIIT sessions were conducted online, in real time, from 9.30 to 10.30 a.m. with the use of the MS Teams® platform on Mondays, Wednesdays, and Fridays, except one Monday, which was a holiday (in total, there were 23 sessions). All sessions were led by the principal researcher, a qualified fitness professional and certified Pregnancy and Postnatal Exercise Specialist according to European standards (Szumilewicz et al., 2022). Adherence to the program was monitored via email and phone contact. Women took part in 19 ± 4 sessions on average (80% of the entire HIIT exercise program). They rated the HIIT sessions (the intensive interval part along with about 30 minutes of lower-intensity exercises) at an average of 7 ± 0.7 on a 0–10 RPE scale, on average. We described the details of the intervention in our previous publication (Wilczyńska et al., 2023).

The control group (EDU group) took part in educational sessions about healthy living, PA during the perinatal period, and various aspects of pregnancy and motherhood (the same educational content was provided to the HIIT group). These online educational classes were held live once a week for eight weeks (for both HIIT and EDU groups). Women in the EDU group were encouraged to exercise independently and aim to meet at least the recommended PA level (a minimum of 150 minutes per week of moderate to vigorous intensity). They were asked to keep a diary documenting all their physical activities, including both structured exercise sessions and daily activities lasting at least 10 minutes, such as house cleaning, gardening, and shopping. Unlike the HIIT group, the EDU group did not use heart rate monitors to track exercise intensity but used the RPE scale and the Talk Test. The recommended exercise intensity was such that participants felt a noticeable increase in breathing frequency, but not above the level that interfered with conversation. On average, EDU participants reported 20 activity sessions with an average intensity of 6 ± 0.6 on the 0–10 RPE scale.

After the 8-week intervention, participants in both groups were encouraged to continue PA during pregnancy (HIIT in the HIIT group and moderate to vigorous PA in the EDU group), until birth. Both groups were educated how to start exercise after birth and received the same written instructions with examples of postpartum exercises.

During the entire study, all participating women remained under standard obstetric care. Both HIIT and EDU interventions were not associated with any negative effects on the course of pregnancy or on childbirth parameters. We collected data on obstetric and neonatal postpartum outcomes, using an online questionnaire (based on medical records).

This research was performed according to the principles of the WMA Declaration of Helsinki and with the approval of the Bioethics Commission at the [*blinded*], no. [*blinded*]. All participants were asked to sign the informed consent prior to testing. The study protocol was registered in ClinicalTrials.gov [*blinded*]. 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). No

data manipulations were performed. Outcomes of this study are available under the name: Dataset- Influence of High Intensity Interval Training on Postnatal Depression, DOI: 10.17632/s32pbtc6dx.1 (Walczak-Kozłowska et al., 2024).

Statistical analyses were performed using the IBM Statistical Package for the Social Sciences version 27.0 (IBM Corp., Armonk, New York, USA), with the statistical significance set to $p < 0.050$. The analysis of the normality of the distribution of study variables was developed using the Kolmogorov–Smirnov test (the details are provided in Supplementary Material S1'). Inter- and intra-group mean differences were analyzed by the Student's t-test or analysis of variance (ANOVA) test when appropriate. In the case of distributions which were significantly different from the normal distribution, we used the non-parametric Friedman test, Mann–Whitney U test, and the Wilcoxon T test for the assessment of inter- and intra-group differences, respectively. Additionally, Chi-square was used to evaluate the differences in frequencies. We also conducted Intention-to-treat (ITT) analyses using linear interpolation to estimate the results of participants who were lost during the study (see Supplementary Materials 'S2' and 'S3'). The results of the correlation analyses are included in Supplementary Materials 'S4'-'S8'.

RESULTS

Depression symptoms

We did not find any between-group differences in the severity of depression symptoms measured with BDI-II, however, we found within-group differences (across all three assessments) both in the HIIT as well as EDU group (see Tables 2 and 3, and Figure 2).

The Edinburgh Postnatal Depression Scale was used only during Time 3 assessment. We found no significant between-group differences in the severity of postpartum depression symptoms (see Table 2). Taking the value of 10 points as the cut-off point, we can estimate that in the EDU group, 21.1% of women received a heightened result, and in the HIIT group, it was 23.5% (the difference was non-significant: $X^2 = .043$, $p = .836$). Of note, in the EDU group, there were twice as many women with increased severity of PPD symptoms compared to the HIIT group (15.80% vs. 8.70%; see Figure 3).

Psychological well-being

In case of The Flourishing Scale, we found no between-group differences in any of the three assessments (see Table 2 and Figure 4); however, within-group differences were found in the EDU group (see Table 3).

Physical and mental health

There were no significant between-group differences in physical health indicators in any of the assessments (see Table 2 and Figure 5); nor were there any within-group differences (see Table 3). We also found no significant between-group differences in mental health indicator in any of the three assessments (see Table 2 and Figure 6). We found significant within-group differences only in the EDU group (see Table 3).

TABLE 2 Between-group differences.

Variable	Time 1			Time 2			Time 3		
	HIIT ($M \pm SD$), n = 34	**EDU ($M \pm SD$), n = 19**	**Between-group difference**	**HIIT ($M \pm SD$), n = 34**	**EDU ($M \pm SD$), n = 19**	**Between-group difference**	**HIIT ($M \pm SD$), n = 34**	**EDU ($M \pm SD$), n = 19**	**Between-group difference**
Depression symptoms (BDI-II score)	5.68 ± 4.44	5.47 ± 3.75	$t = 0.168$; $p = .867$; $d = .048$	5.03 ± 3.83	3.84 ± 1.95	$Z = -1.029$; $p = .304$; $r = .141$	9.03 ± 6.60	9.53 ± 5.39	$Z = -0.632$; $p = .527$; $r = .087$
Postpartum depression symptoms (EPDS score)	N/A	N/A	N/A	N/A	N/A	N/A	5.65, ± 4.41	7.42 ± 5.17	$t = -1.320$, $p = .193$; $d = .378$
Psychological well-being (FS score)	51.44 ± 3.98	51.68 ± 4.04	$Z = -0.282$; $p = .778$; $r = -.039$	51.94 ± 4.00	51.84 ± 3.59	$Z = -0.245$; $p = .807$; r = .034	48.56 ± 7.28	47.74 ± 7.67	$Z = -0.327$; $p = .744$; $r = -.045$
Physical health (PCS score)	48.45 ± 6.98	46.54 ± 6.51	$t = -0.979$; $p = .332$; $d = .280$	48.48 ± 7.59	46.20 ± 6.58	$Z = -1.076$; $p = .282$; $r = .148$	47.74 ± 9.08	47.67 ± 7.76	$Z = -0.334$; $p = .738$; $r = .046$
Mental health (MCS score)	48.46 ± 7.23	52.03 ± 6.51	$t = -1.785$; $p = .080$; $d = -.511$	52.12 ± 5.85	54.14 ± 4.02	$Z = -1.252$; $p = .211$; $r = .172$	49.54 ± 9.75	44.96 ± 9.83	$Z = -1.792$; $p = .073$; $r = .246$
Weekly PA (METs)	2819.79 ± 2298.56	2595.53 ± 2861.27	$Z = -0.742$; $p = .458$; $r = .102$	3173.02 ± 2220.43	2760.92 ± 3511.02	$Z = -1.345$; $p = .179$; $r = .185$	3478.91 ± 1984.29	2841.63 ± 1412.41	$Z = -1.206$; $p = .228$; $r = .169$

Note: In case of variables with a distribution close to normal distribution, we used parametric testing with Student t test, and in case of variables with a distribution significantly different from the normal distribution, we used non-parametric testing with Mann–Whitney *U* test. In order to estimate effect size, we used Cohen's *d* for testing with Student t test and rank-biserial correlation coefficient (*r*) for testing with Mann–Whitney *U* test.

TABLE 3 Within-group differences.

Variable	Depression symptoms (BDI-II score)		Psychological well-being (FS score)		Physical health (PCS score)		Mental health (MCS score)		Weekly PA (METs)	
Group	HIIT, n = 34	EDU, n = 19	HIIT, n = 34	EDU, n = 19	HIIT, n = 34	EDU, n = 19	HIIT, n = 34	EDU, n = 19	HIIT, n = 34	EDU, n = 19
Within-group differences[1]	**X^2 = 11.919; p = .003; W = .175**	**X^2 = 12.873; p = .002; W = .339**	X^2 = 5.509; p = .064; W = .081	**X^2 = 9.710; p = .008; W = .256**	X^2 = 1.471; p = .479; W = .022	F = .425; p = .657; η_p^2 = .009	X^2 = 3.250; p = .197; W = .051	**X^2 = 7.895; p = .019; W = .208**	X^2 = 3.417; p = .181; W = .054	X^2 = 1.263; p = .532; W = .033
Post-hoc analyses										
Difference[2]: Time 1 – Time 2	Z = −1.444; p = .149; r = .248	t = 1.650; p = .116; d = .379	N/A	Z = −.211; p = .833; r = .048	N/A	N/A	N/A	Z = −.684; p = .494; r = .157	N/A	N/A
Difference[2]: Time 1 – Time 3	**Z = −2.856; p = .004; r = .490**	**Z = −2.610; p = .009; r = .599**	N/A	**Z = −2.306; p = .021; r = .529**	N/A	N/A	N/A	**Z = −2.535; p = .011; r = .581**	N/A	N/A
Difference[2]: Time 2 – Time 3	**Z = −3.091; p = .002; r = .530**	**Z = −3.499; p < .001; r = .803**	N/A	**Z = −2.253; p = .024; r = .517**	N/A	N/A	N/A	**Z = −3.219; p = .001; r = .738**	N/A	N/A

[1]In case of variables with a distribution close to normal distribution, we used parametric testing with ANOVA, and in case of variables with a distribution significantly different from the normal distribution, we used non-parametric testing with the Friedman test. n order to estimate effect size, we used partial eta-squared for testing with ANOVA and Kendall's W for testing with the Friedman test.

[2]In case of variables with the distribution close to normal distribution, we used parametric testing with dependent samples Student's t-test, and in case of variables with a distribution significantly different from the normal distribution, we used non-parametric testing with the Wilcoxon test. In order to estimate effect size, we used Cohen's *d* for testing with Student t test and the rank-biserial correlation coefficient (*r*) for testing with the Wilcoxon test.

Note. Bold type indicates a significant difference in the outcome variable.

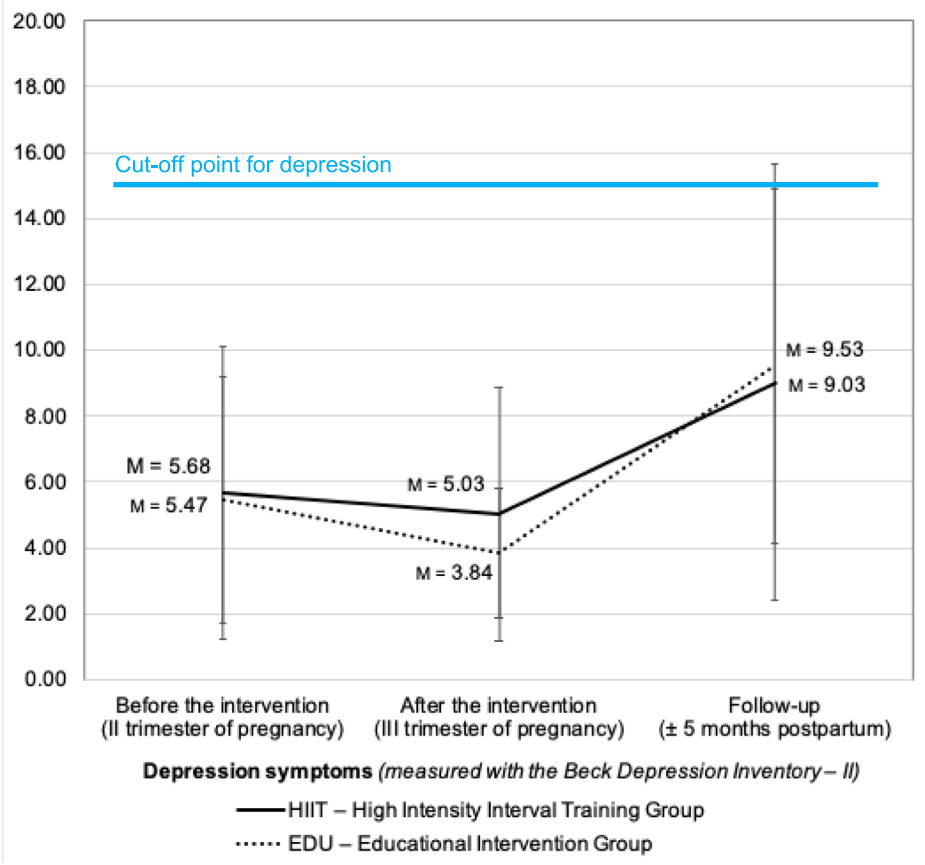

FIGURE 2 Between-group differences in the severity of depression symptoms (measured with the Beck depression inventory – II). Note. The figure shows standard deviation (SD) bars.

Level of physical activity during pregnancy and postpartum

There were no significant between-group differences in any of the assessments in the level of PA (see Table 2 and Figure 7); nor there were any within-group differences (see Table 3).

Additional analyses

We performed additional analyses to deepen our understanding of the obtained results. We decided to group women based on the variable 'primipara – multipara' (she has not given birth before - she has given birth before). In the HIIT group, the sizes of the groups obtained on the basis of this variable were similar in quantity (18 vs 16); however, in the EDU group, there was a significant disproportion (17 vs 2), therefore, we conducted such analyses only for the HIIT group. We analyzed all variables from each of the three stages of the study (depression symptoms, postpartum depression symptoms – only in the Time 3 assessment, psychological well-being, physical health, mental health, and weekly PA), and it turned out that women who have given birth before obtained better results in the *Flourishing scale* (which measures psychological

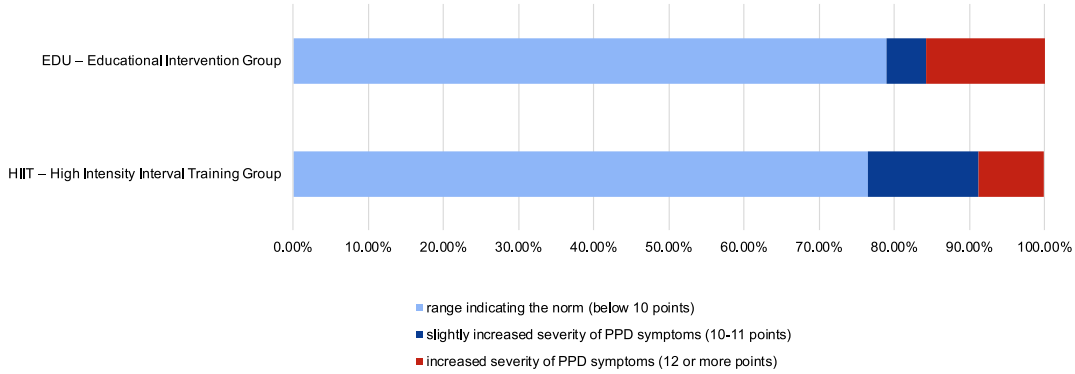

FIGURE 3 Distribution of EPDS results (within cut-off points) in the HIIT and EDU groups in the postpartum assessment (time 3).

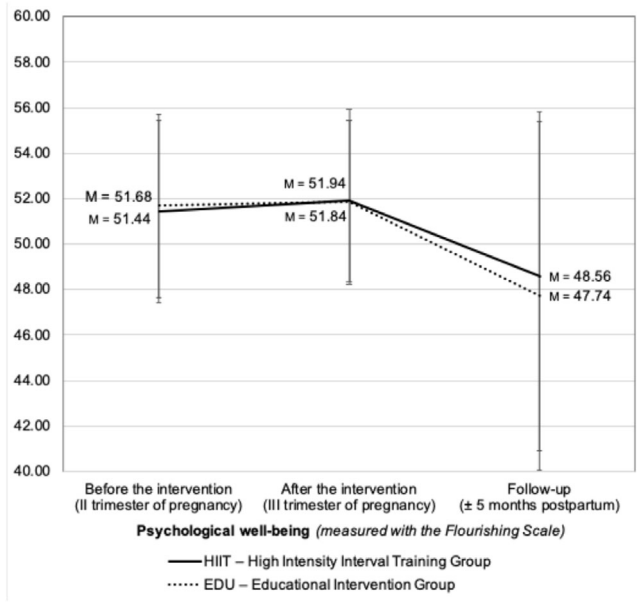

FIGURE 4 Between-group differences in psychological well-being. Note. The figure shows standard deviation (SD) bars.

well-being) in the Time 3 assessment (postpartum). The details of these analyses are presented in table SM-9 in the Supplementary Materials and discussed in the discussion section.

DISCUSSION

In this study, we aimed to investigate the long-term effects of an 8-week prenatal supervised HIIT and self-performed moderate to vigorous PA interventions on postpartum recovery and mental health. The most important findings of our study are related to the mental health indicator, which decreased significantly in the EDU group in the postpartum assessment, while

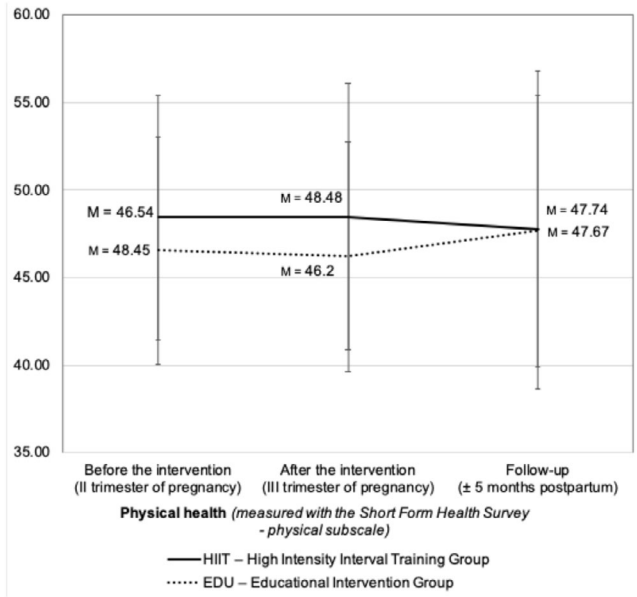

FIGURE 5 Between-group differences in physical health. Note. The figure shows standard deviation (SD) bars.

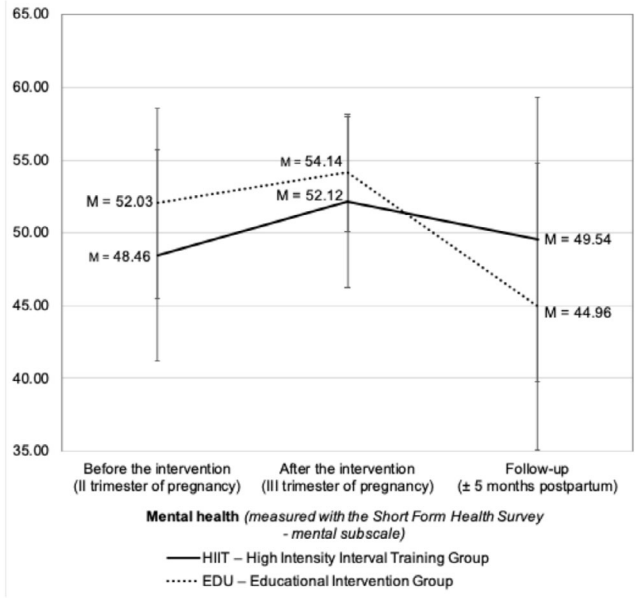

FIGURE 6 Between-group differences in mental health. Note. The figure shows standard deviation (SD) bars.

remaining stable in the HIIT group. Moreover, there were no differences between groups in the intensity of depressive symptoms, which slightly increased in both groups but were relatively low as for the postpartum period. A similar observation concerned well-being indicator;

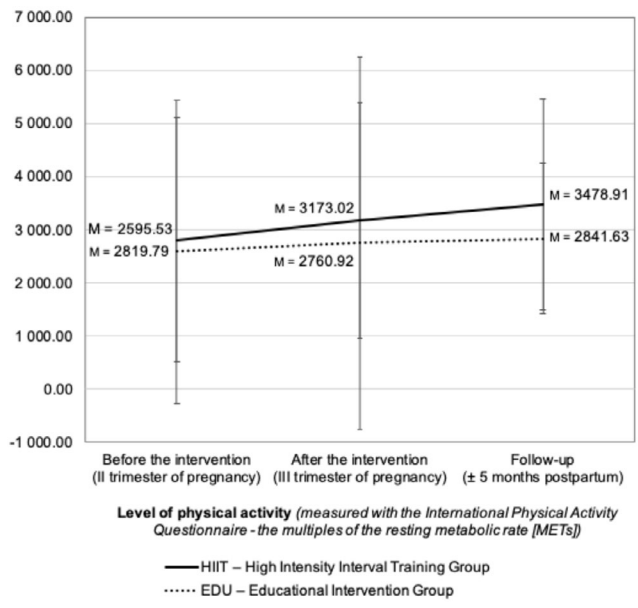

FIGURE 7 Between-group differences in the level of physical activity in metabolic equivalents (METs). Note. The figure shows standard deviation (SD) bars.

however significant decrease was observed only in the EDU group. Of note, in the HIIT group, there was no higher percentage of women with severe symptoms of postpartum depression compared to the EDU group. Moreover, the assessment of physical health was similar in both groups in all measurements, and no significant changes were observed after delivery. When it comes to the level of PA, there were no differences after delivery in the groups - both strategies turned out to be equally effective in maintaining the level of PA.

Our study revealed that both women participating in HIIT interventions and those undergoing educational interventions did not differ in depression symptoms (both during pregnancy and postpartum), however, women from both groups experienced an increase in depressive symptoms after childbirth. It should be noted that the average results achieved by the participants in each group were within the normal range (both for the BDI as well as EPDS). Moreover, during the postpartum period, we found that there was a need to extend the clinical diagnostics among 21.1% women from the EDU and 23.5% of women from the HIIT group (they scored 10 points and above on the EPDS). Although the increase in points was slightly greater in the comparative group (EDU), as we mentioned - intergroup differences in the severity of depressive symptoms were insignificant, which is confirmed by the results of both the screening test for postpartum depression (the Edinburgh Postnatal Depression Scale) and the scores from the clinical tool (the Beck Depression Scale). These results indicate that both interventions demonstrate similar effectiveness in terms of preventing postpartum depressive disorders, and the increase in depressive symptoms still occurs despite participation in the intervention program. This finding is consistent with some research results indicating an increase in the severity of depressive symptoms after pregnancy (e.g. Putnick et al., 2020), although there are also studies indicating no significant changes in the trajectory of symptom severity or even indicating a reduction in this severity (e.g. Fredriksen et al., 2017). Nevertheless, there is still little research on the trajectory of depressive symptoms in the perinatal period, and many existing studies

included only one measurement during pregnancy and a measurement after childbirth very early (within the first two weeks), when symptoms may be confused with *baby blues*. Thus, the results of our study partially fill the gap in understanding the trajectory of changes in the severity of depressive symptoms after childbirth in physically active women. Especially considering that the analyzed participants were subjected to two different interventions, as well as since women were assessed after about 5 months after giving birth, when the symptoms may become more severe (see American Psychiatric Association, 2013; World Health Organization, 2004).

In terms of psychological well-being, we observed no intergroup differences in all measures. However, after giving birth, a significant decrease was observed in the EDU group. In this case, we can perhaps conclude with some caution that the HIIT intervention may be more protective against the decline in psychological well-being typical for the perinatal period than the EDU intervention. In the EDU group, psychological well-being and mental health after childbirth were related to the initial psychological well-being before the pregnancy intervention. However, in the HIIT group, postpartum psychological well-being was more related to the assessment of mental health after the pregnancy intervention. It may be that the positive experience of engaging in HIIT training has protective value for psychological well-being after pregnancy. However, there is an important point to note here: additional analyses have shown that the EDU group was dominated by primiparous women, and perhaps this fact could explain the significant decrease in well-being in this group (since we observed that in the HIIT group there were proportionally more multiparous women than in the EDU group, and they had better psychological well-being scores). However, this is a hypothesis that would require further studies with purposeful selection of the group (where selection and allocation based on the variable 'primiparous-multiparous' would be controlled). Here, we can only hypothesize based on the results achieved by the HIIT group that the increased proportion of primiparous women may account for this change in the EDU group. In further research, it is worth considering how to increase the positive experiences of engaging in PA during pregnancy in order to increase the chances of stable well-being after giving birth, but also it is worth considering purposive sampling and maintaining proportions in the 'primipara-multipara' variable when allocating to groups.

The above observation is related to the findings regarding changes in the mental health indicator: although there were no significant differences between groups in any of the measurements, in the EDU group, there was a significant decline in this aspect after childbirth, which was not observed in the HIIT group. Therefore, it can be concluded with some caution that HIIT intervention may be a potential protective factor for overall postpartum mental health conditions. This statement can be supported by evidence from our previous two studies, where we observed that the EDU group experienced a decline in cardiorespiratory fitness parameters (VO_2max), while the HIIT group remained stable in this aspect. Moreover, the HIIT group exhibited an increase in cortisol levels and, at the same time, had significantly higher mental health scores compared to the EDU group, which we interpret as positive stress—eustress. This phenomenon can also be explained physiologically, as previously described, where the HPA axis, CRH, and ACTH play a role in cortisol release after high-intensity exercise, leading to a shift toward catabolic processes that facilitate the organism's adaptation. (Wilczyńska et al., 2022, 2023). In this context, the findings of the current study provide important evidence that HIIT exercises during pregnancy do not pose a threat to the mental health of women in uncomplicated pregnancies. This supports the notion that the physiological stress induced by HIIT may contribute to adaptive benefits rather than negative psychological outcomes. However, this observation requires exploration and confirmation in further research. It is also worth

considering the consequences for mental health later. It should also be mentioned that in the HIIT group, a relationship was observed between the postpartum assessment of mental health and the assessment of this aspect of health during pregnancy (immediately before and after the intervention). Perhaps this is some evidence of greater stability in perinatal mental health in women practicing HIIT compared to women who received only the educational intervention. However, this hypothesis also requires further exploration.

When it comes to assessing physical health, we observed no differences between groups in all measurements, as well as no differences over time in both groups. Therefore, it can be concluded that both the HIIT intervention and the EDU intervention allow to "maintain" the physical health of women in the perinatal period at a similar level as the initial one (see also Wilczyńska et al., 2022). This is a very important observation, as the trajectory of changes in the assessment of physical health during pregnancy and after childbirth in connection with HIIT intervention during pregnancy has not been studied so far.

Finally, we would like to point out that both interventions proved to be equally effective in maintaining PA after childbirth (there were no inter-group differences at any stage of the study, and no intra-group differences in any of the study groups in the level of PA). PA seems to be a significant correlate of many psychological variables: the severity of depressive symptoms, psychological well-being, and mental health indicators.

Understanding the interplay between PA, prenatal mental health, and postpartum depression is paramount for developing effective interventions and support systems for expectant and new mothers. By elucidating the complex relationships between these variables, healthcare and exercise professionals can tailor preventive strategies and therapeutic approaches to mitigate the risk of mental health problems and promote the holistic well-being of pregnant and postpartum women.

Limitations and further steps

Although participants were supposed to continue their PA on their own and were encouraged to resume their pre-pregnancy intensity and volume of exercise as soon as medically safe, we were lacking the continued monitoring of PA level in the postpartum period in both groups. It is worth taking this aspect into account in subsequent similar studies. Moreover, in future studies, it would be worth starting the supervised exercise intervention as early as possible, gradually implementing the HIIT program. In future studies, it is worth considering maintaining the proportions during sample selection in terms of the 'primipara-multipara' variable, because this variable may influence and explain some results. Also, the sample size is relatively small and consists exclusively of Caucasian women, which limits the generalizability and applicability of the results to other ethnic and socioeconomic groups. However, it is important to note that this population represents a hard-to-reach sample. Moreover, the role of a supportive partner should be considered in future studies as a potentially influential variable in the context of mental health following childbirth. Another important research issue concerns the evaluation of the effectiveness of high-intensity interval training in women with complicated or high-risk pregnancies. For many years, opinions not supported by scientific evidence have suggested that high-intensity exercise may pose risks to the course of pregnancy and fetal development. However, in light of current – albeit limited – data, such claims appear not only unfounded but potentially harmful, as they discourage the use of beneficial exercise stimuli that may support the optimal functioning of both the mother and the fetus.

One of the weaknesses of our work was the unequal number of participants in both groups at the final stage of analysis, making it harder to analyze and interpret data. Many factors could have determined higher participants' adherence to the intervention in the HIIT group. First, each HIIT session (three times a week) was supervised by an exercise specialist. In contrast, the EDU group met with an exercise specialist once a week for theoretical classes and undertook physical activity independently. Therefore, our results may provide evidence of greater adherence to exercises in supervised interventions compared to unsupervised ones. The second reason why more women dropped out of the EDU group may be their disappointment related to the allocation to the intervention. In the invitation to participate in the project, we emphasized the novelty of the HIIT intervention and its potential maternal and neonatal benefits. We do not know to what extent these issues could have influenced the analysed results.

CONCLUSIONS

This study investigated the short and long-term effects of an 8-week prenatal supervised online HIIT and self-performed moderate to vigorous PA interventions on postpartum recovery and mental health. The findings revealed that both HIIT and educational (EDU) groups maintained similar physical health and activity levels postpartum. Groups did not differ in the severity of depression symptoms, psychological well-being, and mental health both during pregnancy (before and after interventions) as well as in postpartum. However, the HIIT intervention appears to have a more protective effect on postpartum mental health and well-being than the EDU intervention. These results underscore the need for comprehensive, varied interventions, including ongoing PA, to sustain mental health improvements. Further research is needed to analyze these findings and develop effective systems to support women's mental health during the perinatal and postnatal period.

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CONFLICT OF INTEREST STATEMENT
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT
The data set associated with the paper is available under the name: Dataset- Influence of High Intensity Interval Training on Postnatal Depression, DOI: 10.17632/s32pbtc6dx.1

ETHICS STATEMENT
Trial registration: We conducted this study in Poland in 2021. It was approved by the Bioethics Commission at the District Medical Chamber in Gdansk (KB - 8/21). The full study protocol was registered in ClinicalTrials.gov (NCT05009433).

ORCID
Dominika Wilczyńska https://orcid.org/0000-0002-4332-0157

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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