The influence of migraine on cognitive functioning, sleep quality and mental health outcomes in postpartum women, with and without hypertensive disorders of pregnancy: a cross-sectional study

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Abstract

Cognitive impairment in early postpartum women is a prevalent phenomenon due to numerous cognitive, physiological, and psychological stressors, with comorbidities such as migraine and hypertensive disorders of pregnancy (HDP) potentially further exacerbating these impairments. Migraine, which is a neurovascular disease affecting a considerable number of women of reproductive age, has pathophysiological overlap with hypertensive disorders of pregnancy (HDP), particularly in vascular damage affecting cognitive functioning. To our knowledge, there is currently no literature examining cognitive impairment during the early postpartum period in this specific population. Therefore, this cross-sectional study assessed the influence of migraine on cognitive functioning, sleep quality, and mental well-being in postpartum women with and without HDP up to 12 months postpartum. Cognitive tests covered verbal memory, executive functioning, processing speed, verbal fluency, motor coordination, and visuospatial functions. Sleep quality and depression status were assessed through PSQI and CES-D scales. Data were analyzed using multivariate linear regression analysis with and without controlling for a subset of confounders and stratified by HDP status. In total, 233 postpartum women were included. No differences were found in any measure of cognition, sleep quality, or depression between those women with and without migraine. The lack of difference indicates that having migraine, which is a chronic condition, does not impose additional cognitive, sleep-related, or psychological burden to women within the first year postpartum other than what is typical of them as a group. These findings may provide a clinical basis for reassurance to women suffering from migraine, especially those who also experienced HDP.

Keywords: migraine, hypertensive disorders of pregnancy (HDP), cognitive functioning, sleep quality, mental health, postpartum

Introduction

A common perspective regarding the postpartum phase is that of happiness, joy, and recovery. Women have been expected to consider this the most beautiful period of their lives. However, even though the postpartum period can be a happy and beautiful period for mothers, it is often accompanied by psychological and physical obligations. In reality, women need to deal with considerable hormonal shifts, physical recovery after pregnancy and childbirth and disturbed sleeping patterns (Wu et al., 2025). They frequently experience a decrease in cognitive functioning, sleep quality and mental well-being (Henry & Sherwin, 2012; Okun, 2016; Saharoy et al., 2023). For most postpartum women, these consequences would not be of permanent character. However, for those with underlying health problems related to pregnancy, like hypertensive disorders of pregnancy (HDP) or health problems existing before pregnancy, like migraine, the postpartum phase could place a significantly greater burden on them (Strapasson et al., 2018; Sakurai et al., 2022; Miller et al., 2022; Linfield et al., 2025).

Cognitive impairment, poor quality of sleep, and mental well-being in women during the postpartum period may be further aggravated when they suffer from certain illnesses, such as migraine (Miller et al., 2022). Migraine is the largest contributor to disability-adjusted life years (DALYs) among females of reproductive age. Most of the patients suffering from migraine are women of the reproductive age group. It is therefore essential to understand how migraine responds within the postpartum state, not only from a medical standpoint, but also from the point of neurobiological stress experienced by women after giving birth (Cen et al., 2024). Migraine is a neurovascular condition involving changes in vascular physiology and inflammation, both of which contribute to reduced cerebral blood flow and neural conduction. The trigeminovascular system increases the secretion of CGRP (calcitonin gene-related peptide), causing vasodilation. This activates trigeminal nerves, which in turn transmit impulses to cortical and subcortical brain regions, resulting in the perception of pain (Ashina, 2020). Usually, migraine clinically presents itself as a series of moderate to severe pulsating attacks occurring on one side of the head. The attack of this headache also brings out feelings of nausea, vomiting or aversion to light and noise (Cen et al., 2024). Beyond these attacks, the presence of these physiological dysfunctions and inflammation could negatively affect patient's cognitive performance, particularly patient's executive functioning and attention (de Araújo et al., 2012). One pathway through which vascular dysfunction could have an impact on cognitive abilities can be seen by means of decreased blood flow that occurs during migraine. This decrease in blood flow can slow down the process of protein synthesis in the brain, which, in turn, leads to ischemia and neurocognitive disturbances, including dementia (Ogoh, 2017; Widmer et al., 2014). This

pathophysiology suggests that migraine might have an effect on cognitive functioning in postpartum women.

In order to gain insight into how migraine could also be related to sleep and mental well-being, the shared pathophysiological mechanisms that underlie these issues need to be examined. The hypothalamus plays a significant role in this aspect. The suprachiasmatic nucleus (SCN), otherwise referred to as the hypothalamic clock, regulates the rhythm of the sleep-wake cycle through neuromediator release, which includes orexin, among others (Moore, 2007). Moreover, while the hypothalamic orexinergic system is associated with sleep due to the release of orexins, it is also associated with the regulation of pain through the trigeminovascular system (Lin et al., 2016). The SCN, on the other hand, is responsible for regulating the cyclical secretion of melatonin, which promotes sleep and possesses anti-nociceptive effects. Patients suffering from migraine demonstrate lower concentrations of melatonin, which was shown to inhibit trigeminovascular activation, directly linking disrupted sleep to migraine pathophysiology (Holland, 2014). Beyond sleep, the hypothalamus regulates mood and mental status through hormonal secretion, specifically of corticotropin-releasing hormone and cortisol, whose dysregulation could impact the mental health status and cause depression (Bao et al., 2008; Antonijevic, 2008). This overlap in pathophysiology between migraine, sleep quality and mental health, could imply that they are related to each other.

The situation becomes more complex as HDP, particularly preeclampsia, also may be related to migraine, as they share underlying vascular dysfunction and systemic inflammation (Miller et al., 2022). Preeclampsia is considered to be a placental disease characterized by poor perfusion of the placenta due to incomplete trophoblast invasion. Trophoblast cells are crucial in creating a proper blood flow from the mother to the foetus. Reduced trophoblast invasion results in less widening of the spiral arteries of the mother, which ultimately leads to less blood flow to the placenta. Another effect of reduced trophoblast invasion is formation of oxidative stress, which impairs the inner layer within blood vessels and therefore leads to endothelial dysfunction (Sánchez-Aranguren et al., 2014). Endothelial dysfunction makes women with HDP vulnerable to further vascular damage. Moreover, vascular damage does not fully normalize after delivery, but may persist years after delivery (Tomimatsu et al., 2019). The long-term consequences are meaningful as HDP is associated with higher risks of developing later-life (vascular) dementia (Basit et al., 2018) and women who developed a hypertensive disorder during pregnancy have been shown to perform worse on cognitive tests, especially those concerning working memory and verbal learning even 15 years after pregnancy (Adank et al., 2021). These associations could be explained as endothelial dysfunction, caused by HDP, leads to an impaired blood-brain barrier (BBB). Higher permeability of the BBB results in blood leakage

into the brain, which may cause inflammation in the brain due to cerebrovascular damage (Kaur et al., 2023). Both migraine and HDP affect vascular structures, making the risk of cognitive impairment, poor sleep quality, and psychological symptoms higher in pregnant women who suffer from both diseases as opposed to women without HDP (Mielke et al., 2023; Heydari et al., 2025).

While the hypothalamic pathway links migraine to sleep disturbance, HDP introduces an additional, distinct route to sleep disruption which is bidirectional. There is an increased risk of development of HDP associated with sleep apnea, insomnia, and other sleeping disorders (Abbasi et al., 2024), while HDP itself may also result in sleep problems (Heydari et al., 2025). It is thought that inflammation causes interference with sleep regulatory systems, like the hypothalamus, resulting in fragmented sleep (Heydari et al., 2025). It is necessary to pay attention to sleep in this population group, since sleep disturbances may indicate increased risk of developing cardiovascular disease after HDP. Mental disorders and HDP seem to have a bidirectional connection too. Both depression and anxiety have been shown to be associated with increased risk of developing preeclampsia (Kurki et al., 2000), while women with severe preeclampsia have reported lower quality of life regarding their mental state (Stern et al., 2014). Although the mechanisms underlying this association are not yet fully understood, this shows the importance to consider HDP as a condition with a serious impact on the quality of life of women (Stern et al., 2014).

Taken together, there is an indication of a compounded risk associated with the presence of migraine and HDP in postpartum women. The postpartum period itself constitutes a considerable challenge to cognitive performance, quality of sleep, and mental well-being, which is something all postpartum women may experience on a certain level (Wu et al., 2025). In addition to this, a first layer of risk is created by the pathophysiology of migraine. These include the endothelial dysfunction and inflammatory components (Cen et al., 2024). On top of this, a second layer of risk is added by HDP via the process of endothelial dysfunction along with inflammation of a persistent nature, often not completely recovered shortly after birth (Tomimatsu et al., 2019). As these two conditions have an overlap in pathophysiology, the combined presence of both of them may pose risks that are greater than just an additive effect. Nonetheless, it has not been established how these two conditions affect postpartum outcomes when present simultaneously. Most studies that have been investigating this area have been focused on examining the impact of HDP on women's lives within a decade after pregnancy (Adank et al., 2021; Basit et al., 2018), while only few studies have been focused on examining the impact of HDP or migraine within the first year after childbirth. The current study directly fills this gap. As far as we know, there has been no research that investigates the impact of both migraine and HDP on cognition, sleep, and psychological well-being in the first year after

childbirth. It is very important from a clinical perspective, because if such combination has an additional impact on these variables apart from the common impact experienced by all women in the first postpartum year, this fact requires further attention. On the contrary, if no additional negative effect is found, this fact will give some positive information to postpartum women who might worry about their state.

This study therefore investigates the influence of migraine on cognitive functioning in women within 12 months postpartum, and whether hypertensive disorders of pregnancy modifies these associations. Cognitive functioning will be measured using validated cognitive tests, containing the 15 Word Learning test (15WLT), Stroop test, Letter-Digit Substitution task, Word Fluency test, Purdue Pegboard test and the Design Organisation test. This testing battery is based on the studies of Adank et al. (2021) and Hoogendam et al. (2014), as these cognitive tests collectively assess a broad range of cognitive domains. Furthermore, we will investigate the influence of migraine on sleep quality and mental health outcomes in postpartum women within 12 months postpartum, with further stratification of the presence of hypertensive disorders of pregnancy. This will be measured using the Pittsburgh Sleep Quality Index (PSQI) questionnaire for sleep quality, and the Center for Epidemiological Studies – Depression (CES-D) questionnaire to measure depressive symptoms.

Based on the similar pathophysiological aspects between migraine, HDP and the outcome variables, it can be inferred that migraine and HDP will negatively influence cognitive functioning, sleep quality and psychological state of postpartum women. The reasoning provided is in line with existing evidence related to the negative effect of HDP on cognitive functions in women previously diagnosed with HDP (Adank et al., 2021), as well as the connection between preeclampsia and reduced sleep quality observed in Heydari et al. (2025) and mood disturbances and preeclampsia reported in Kurki et al. (2000). Nevertheless, it should be noted that the postpartum stage is characterized by the occurrence of hormonal shifts, reduced sleep and emotional stress in all women (Henry et al., 2012). Given that hormonal changes constitute triggers for migraine (Krause et al., 2021), it raises the question whether the effects of migraine on cognition, sleep and mental health can be measured in such difficult biological and psychological environment.

Method

Participants

Women that gave birth in the Erasmus Medical Center (EMC) were contacted to participate in the PERFORM study. A subset of these participants was subsequently asked to take part in an additional component of the study involving cognitive testing. In total, 233 participants agreed and completed these tests. The women had a mean age of 33.7 (5.0), ranging from 22 to 51 years old.

The included women were fully informed and capable of understanding the purpose of the study. In addition, they signed the given written informed consent, which is approved by The Medical Ethics Review Committee of the Erasmus MC (MEC-2020-0658). Women were excluded from the study if they were not capable of understanding the Dutch language or aged below 18 years old. If there was contact information missing (e-mail address and/or telephone number), a miscarriage before 16 weeks of pregnancy of a termination of pregnancy (TOP), the women were excluded as well.

The participated women were divided into two groups: normotensive women during pregnancy and women with pre-existing hypertension during pregnancy. The second group consisted of women with (severe) preeclampsia, gestational hypertension, superimposed hypertension/preeclampsia or HELLP syndrome, using the International Society of the Study of Hypertension in Pregnancy's (ISSHP) standards. HELLP syndrome is a severe variant of preeclampsia, characterized by Hemolysis (the abnormal breakdown of red blood cells), Elevated Liver enzymes, and Low Platelets. Endothelial damage in the body leads to microvascular thrombosis, which blocks the flow of blood to the liver, causing damage to liver cells and resulting in liver failure in serious conditions (Petca et al., 2022).

The following guidelines were applied to diagnose hypertensive disorders, with the necessary information retrieved from the participants' clinical records, assessed via the hospital's clinical system. These records contain clinical data of the participant, like blood pressures and lipid values. Gestational hypertension is characterized by a SBP ≥ 140 mmHg or a DBP ≥ 90 mmHg after twenty weeks of gestation, with previously normal blood pressures. No proteinuria (the presence of excess protein in the urine) or features of severe preeclampsia should be present. Preeclampsia is present when a SBP ≥ 140 mmHg or DBP ≥ 90 mmHg is measured on two separate moments or a SBP ≥ 160 mmHg or DBP ≥ 110 mmHg is measured on a single moment; proteinuria should be present. If those features are accompanied by a syndrome of hemolysis, elevated liver enzymes or low platelets, the woman is diagnosed with the HELLP syndrome.

Migraine diagnosis was done using the ICHD-3 questionnaire. The answers to the migraine questionnaires, completed by the participants, were compared to the criteria of the ICHD-3. Diagnosis was done, in order to see if the women had migraine with aura, migraine without aura, both, or none. The guidelines for migraine diagnosis can be found in the appendix.

Background study

The PERFORM (Pre-Eclampsia and other Risk FactORs in relation to Migraine) study is an observational study which is performed at the EMC in Rotterdam. This study has started in 2021. After providing informed consent, these women were asked to complete a total of three questionnaires at T=0, T=3 and T=12 months postpartum. The choice of these timepoints is based on both scientific and practical considerations. The 12-month follow-up allows the study to investigate the influence migraine and HDP on health outcomes within the first year postpartum. The 3-month follow-up aligns with routine postpartum check-ups for women with hypertensive disorders of pregnancy (HDP) at the Follow-Up Pregnancy and Cardiovascular Evaluation Clinic (FUPEC) at the EMC. This alignment enables the study to make use of existing clinical data, such as blood pressure measurements, lipid profiles, and other relevant laboratory values, thereby maximizing the efficiency and richness of the dataset.

Procedure

After the women that met the inclusion and exclusion criteria were contacted, informed, and agreed to participate in the study, they filled in the informed consent form. At the same time, the baseline questionnaire was sent to the participants (T=0). This questionnaire was a general questionnaire gathering information about intoxications, medication use, age, and body mass index (BMI). After T=3 months and T=12 months postpartum, migraine questionnaires were sent to the participants in order to determine their migraine status. This was done using the guidelines of the International Classification of Headache Disorders 3 (ICHD-3). At T=3 months and T=12 months postpartum, also sleep and mental health questionnaires were sent to the participants. These questionnaires consisted of questions about sleep quality, disturbances, apnea and sleep length, and questions about mental health quality, depression and anxiety.

The women that took part in the cognitive testing, were tested at the EMC. The testing battery consisted of the 15 Word Learning test, Stroop test, Letter-Digit Substitution task, Word Fluency test, Purdue Pegboard test and the Design Organisation test. All participants were tested individually and

by a trained examiner. The total duration of these tests was 45 minutes. The tests were recorded (audio) to enable appropriate analyses of the data and number of correct answers.

Materials

Validated cognitive tests were used. The following cognitive test were administered to assess different domains of cognitive functioning:

- *15 Word Learning test (15WLT)*

  Verbal learning and memory are evaluated using the 15WLT. A list of fifteen words is given to participants over the course of several trials, and they are asked to recall as many words as they can both after each trial and after a pause. After that, they were given a list of thirty words and asked which words they recognized from the list of fifteen words. Immediate recall (sum of scores of the first three trials), delayed recall, and recognition scores are common outcome measures; higher scores implying improved memory function. When evaluating declarative memory, the test has shown strong validity and reliability (Van der Elst et al., 2005).

- *Stroop test*

  The Stroop test assesses the ability to inhibit cognitive interference and measure executive control. Participants must identify the ink color of words that may or may not match the meaning of the word. Reaction time and/or error count are commonly used to measure performance; longer reaction times or more errors when color does not match the meaning of the word, indicate a lack of inhibitory control. In cognitive research, the Stroop task is frequently employed and has demonstrated strong dependability (Scarpina & Tagini, 2017).

- *Letter-Digit Substitution task*

  The LDST assesses executive functioning and processing speed. Within a set amount of time, participants must match letters to matching numerals using a key. The number of accurate substitutions made within limited time is the score; higher scores implying faster processing. According to Van der Elst et al. (2006), the LDST has shown strong reliability and sensitivity to cognitive deterioration.

- *Word Fluency test*

  The Word Fluency test evaluates executive retrieval and verbal functioning. In a predetermined amount of time, participants are required to come up with as many words as they can that fall into a certain category (in this study 'animals'). The primary outcome measure is the total number of right words generated; higher scores indicating improved verbal fluency. This task is frequently employed in neuropsychological evaluation and has proven good reliability (Tombaugh et al., 1999).

- *Purdue Pegboard test*

  The Purdue Pegboard test measures bimanual coordination and manual dexterity. Within a set amount of time, participants must use first their left, then their right and then both hands to insert pins into holes on a board. Higher scores indicate stronger motor coordination. The number of successfully put pins determines the score. Test-retest reliability has been shown to be good (Tiffin & Asher, 1948).

- *Design Organization test*

  The Design Organization Test evaluates perceptual organization and visuospatial skills. Under time limits, participants are required to replicate or arrange visual patterns. Accuracy and completion time are used to score performance; higher accuracy indicating better visuospatial functioning. Although reported reliability varies depending on the particular version utilized, the test has been used in neuropsychological testing (Killgore & Gogel, 2014).

After assessment of these six cognitive tests, the validated Cognitive Failure Questionnaire (CFQ) was conducted. This questionnaires measures self-reported failures in perception, memory and motor function, with a global focus on memory and attention (Broadbent et al., 1982). The test consists of four domains: memory, distractibility, blunders and (memory for) names (Wallace et al., 2002). Results of these cognitive tests had no direct or indirect clinical consequences and were obtained in research context. Therefore, these results were not shared with participants. All recordings were re-examined by an independent researcher, ensuring double validation of the cognitive results.

Statistical analysis

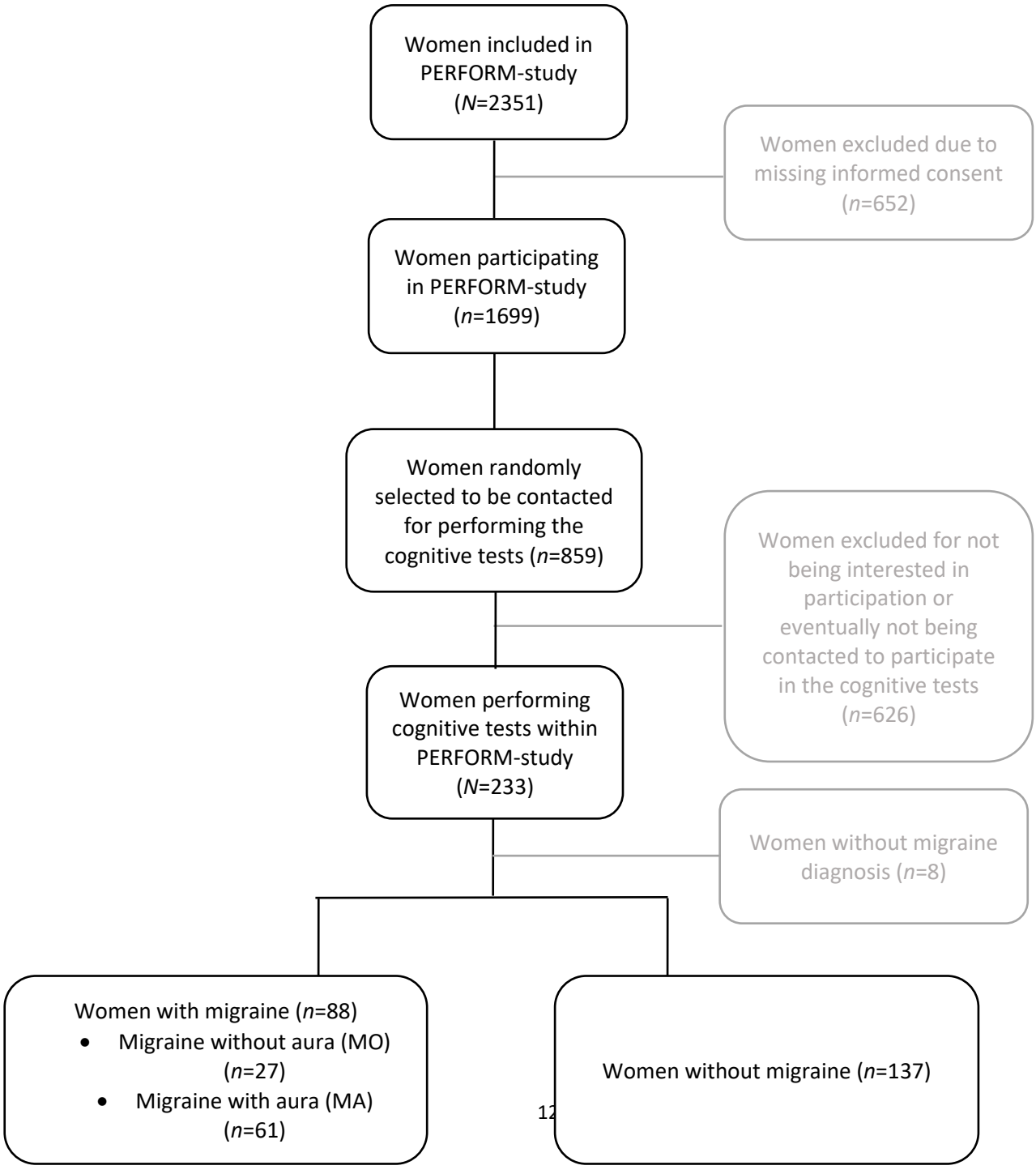
Descriptive statistics were calculated to summarize the baseline characteristics of the participants. Analysis of the objectives were applied using multivariate regression analysis. No major violations were found for the following assumptions. The observations need to be independent and there should be no missing variables. Furthermore, the independent variables have to be linearly related to the dependent variables and the variance of residuals has to remain constant across all levels of the independent variables. The residuals follow a normal distribution when multiple predictors are involved, residuals must not correlate with each other across observations, and finally, there should be lack of multicollinearity. In addition, various confounders were incorporated to control for potential confounders, such as ethnicity, age, BMI, educational level, sleep quality, mental health quality and smoking. These confounders were selected based on earlier research of Adank et al. (2021). Additional confounders were included based as they were likely to affect both migraine and cognition. Alpha was set at <.05. All analyses were performed using IBM SPSS statistics.

Results

The participants consisted of 88 (37.8%) women with migraine and 137 (58.8%) women without migraine, with the migraine status of 8 participants remaining unknown. Figure 1 shows an overview of the participants.

Figure 1

Flowchart of Participants of the PERFORM-study and Cognitive Tests



As shown in Figure 1, a random group of 859 participants of the PERFORM-study was selected to be contacted for performing the cognitive tests. Of this sample, 626 participants did not complete the assessments for various reasons, including lack of interest, uncertainty about participation, failure to attend, or ultimately not being contacted. To account for potential bias, differences in HDP prevalence between women who participated and those who did not were compared; these results are presented in Table 1A in the Appendix. There was a significant difference in the prevalence of HDP between the participants of the PERFORM-study who performed the cognitive tests (enrolled participants, *n*=233), in comparison to the group of participants with no interest (active refusers, *n*=211) ($\chi^2(3) = 8.25$, p=.04), with a higher prevalence of HDP in the group participants who performed the cognitive tests. In addition, a significant difference was found between the enrolled participants and the passive non-participants (*n*=415) ($\chi^2(3) = 11.02$, *p*=.01), with a higher prevalence of HDP in the group of participants who performed the cognitive tests. The passive non-participants consisted of participants who were interested to participate i3n the study at first, but did not perform the tests (*n*=7), but also participants who were doubtful about participation (n=10) or were eventually not contacted after all (*n*=398).

The general baseline characteristics of the participants are presented in Table 1. Table 2 presents the baseline characteristics at time of the cognitive tests. Table 2A and Table 3A in the Appendix present additional general baseline characteristics of the study population, displayed across two parts due to the size of the table. Table 4A presents additional baseline characteristics at time of cognitive tests.

Table 1

General Baseline Characteristics of the Study Population

Characteristics	Total (*N*=233)	Migraine (*n*=88) [a]	No migraine (*n*=137)
Ethnicity [b]			
Caucasian	172 (73.8)	67 (76.1)	102 (74.5)
Other/mixed	55 (23.6)	19 (21.6)	31 (22.6)
Unknown	6 (2.6)	2 (2.3)	4 (2.9)
Educational level [b]			
Low	47 (20.2)	28 (31.8)	17 (12.4)
Medium	45 (19.3)	14 (15.9)	28 (20.4)
High	133 (57.1)	43 (48.9)	88 (64.2)
Unknown	8 (3.4)	3 (3.4)	4 (2.9)
Pregnancy lifetime [c]			
Gravida	2.3 (1.5)	2.2 (1.6)	2.4 (1.4)
Para	1.6 (0.8)	1.6 (0.8)	1.7 (0.8)
Abortus	0.7 (1.1)	0.6 (1.1)	0.7 (1.0)
BMI [c]			
Before pregnancy	26.0 (6.3)	26.1 (6.2)	25.7 (6.3)
After pregnancy	29.9 (6.4)	30.4 (6.7)	29.3 (6.0)
Hypertensive Disorders of Pregnancy [b]			
Normotensive	157 (67.4)	54 (61.3)	95 (69.3)
Gestational hypertension	15 (6.4)	10 (11.4)	5 (3.6)
(Severe) preeclampsia	46 (19.7)	15 (17.0)	31 (22.6)
Superimposed hypertension/preeclampsia	6 (2.5)	4 (4.5)	2 (1.5)
HELLP syndrome	9 (3.9)	5 (5.7)	4 (2.9)
Cognition [b]			
Dyslexia	24 (10.3)	8 (9.1)	15 (10.9)
Color blindness	5 (2.1)	1 (1.1)	4 (2.9)

Note. [a] *Of the sample of participants with migraine, 61 women had migraine with aura and 27 women had migraine without aura.* [b] *Values are displayed as numbers (%).* [c] *Values are displayed as means (SD).*

Table 2

Baseline Characteristics of the Study Population at Time of Cognitive Tests

Characteristics	Total (*N*=233)	Migraine (*n*=88) [a]	No migraine (*n*=137)
Age mother [c]	33.7 (5.0)	33.1 (4.5)	34.1 (5.2)
Months postpartum [c]	8.5 (3.7)	8.9 (3.7)	8.2 (3.7)
Hours of sleep prior to test [c]	6.2 (1.4)	6.2 (1.4)	6.3 (1.5)
Current mood [c]	7.2 (1.2)	7.0 (1.3)	7.3 (1.1)
BMI [c]	27.0 (6.1)	27.4 (6.3)	26.4 (5.7)
Migraine attack within 24 hours before test [b]	6 (2.6)	5 (5.7)	1 (0.7)
Headache within 24 hours before test [b]	71 (30.5)	30 (34.1)	37 (27.0)
Alcohol use within 24 hours before test [b]	27 (11.6)	10 (11.4)	17 (12.4)
Smoking within 24 hours before test [b]	14 (6.0)	8 (9.1)	5 (3.6)
Caffeine intake within 24 hours before test [b]	202 (86.7)	74 (84.1)	120 (87.6)
Presence of (sound-making) baby [b]	12 (5.2)	7 (8.0)	4 (2.9)

Note. [a] Of the sample of participants with migraine, 61 women had migraine with aura and 27 women had migraine without aura. [b] Values are displayed as numbers (%). [c] Values are displayed as means (SD).

The results of subjective perception of the participants on cognitive failure (CFQ) are presented in Table 3. The Mann-Whitney U test was performed, for the data did not meet the assumption of normality. No significant differences were found between the women with and without migraine.

Table 3

Results of Subjective Perception of Participants on Cognitive Failure (N=225)

Cognitive tests	Migraine (*n*=88)	No migraine (*n*=137)	*U*	*Z*	*p*
Cognitive Failure Questionnaire (CFQ) [a]	35.5 (47.0-25.0)	35.0 (43.5-27.0)	5990.00	-0.08	.94
Increase in everyday mistakes over the past 5 years [b]			5747.50	-0.65	.51
No/slight increase	51 (58.0)	71 (51.8)			
Moderate increase	13 (14.8)	28 (20.4)			
Markedly/strong increase	24 (27.3)	38 (27.7)			
Inconvenience in daily life due to these mistakes [b]			5744.00	-0.66	.51
No/slight inconvenience	41 (46.6)	70 (51.1)			
Moderate inconvenience	34 (38.6)	49 (35.8)			
Markedly/strong increase	13 (14.8)	18 (13.1)			
Concern about these everyday mistakes [b]			5691.50	-0.84	.40
No/slight concern	54 (61.4)	90 (65.7)			
Moderate concern	25 (28.4)	39 (28.5)			
Markedly/strong concern	9 (10.2)	8 (5.8)			
Annoyance by these everyday mistakes [b]			5828.00	-0.49	.63
No/slight annoyance	53 (60.2)	87 (63.5)			
Moderate annoyance	16 (18.2)	23 (16.8)			
Markedly/strong annoyance	19 (21.6)	27 (19.7)			
Difficulty in remembering [b]			5809.00	-0.63	.53
Yes	70 (79.5)	104 (75.9)			
No	18 (20.5)	33 (24.1)			

Note. [a] Values are displayed as median (IQR). [b] Values are displayed as numbers (%).

For the first objective, we investigated the influence of migraine on cognitive functioning in women within 12 months postpartum, and whether hypertensive disorders of pregnancy modify these associations. Therefore, Table 4 shows the results of the cognitive test scores for the women with and

without migraine. The independent samples t-test was performed for the immediate and delayed recall of the 15-word learning test and for the total numbers of animals of the Verbal fluency task. The other test scores were compared with the Mann-Whitney U test, for the data did not meet the assumption of normality. No significant differences were found between the results of the women with migraine compared to women without migraine.

Table 4

Results of the Cognitive Tests in Women with Migraine compared to Women without Migraine (N=225)

Cognitive tests	Migraine (*n*=88)	No migraine (*n*=137)	*U*	*Z*	*p*
15-word learning test					
Immediate recall (number of correct answers in 3 trials) [a]	25.4 (6.2)	26.5 (6.3)	1.36 [c]	223 [d]	.18
Delayed recall (number of correct answers) [a]	8.7 (2.5)	8.9 (2.9)	0.78 [c]	223 [d]	.44
Recognition (number of correct answers) [b]	29.0 (30.0-27.0)	29.0 (30.0-27.0)	5702.50	-1.23	.22
Stroop task [b]					
Reading subtask	15.3 (17.3-14.1)	15.4 (17.1-13.8)	5994.50	-0.70	.94
Color naming subtask	20.8 (24.5-18.9)	20.7 (23.0-19.1)	5885.50	-0.30	.77
Interference subtask	33.6 (37.4-29.2)	32.6 (38.6-28.9)	5998.00	-0.06	.95
Letter digit substitution task [b]	41.0 (43.8-36.3)	41.0 (45.0-37.0)	5791.50	-0.50	.62
Verbal fluency task					
Number of animals after 15 sec [b]	11.0 (13.0-10.0)	11.0 (13.0-9.0)	5341.50	-0.13	.90
Total number of animals [a]	26.4 (7.3)	26.8 (6.7)	-0.39 [c]	223 [d]	.70
Purdue Pegboard test [b]					
Number of pins right handed	15.0 (16.0-14.0)	15.0 (16.0-14.0)	5472.00	-1.10	.27
Number of pins left handed	14.0 (15.0-13.0)	14.0 (15.0-13.0)	5918.50	-0.14	.89
Number of pins with both hands	13.0 (13.0-11.0)	12.0 (14.0-12.0)	5758.50	-0.49	.63
Design organization test [b]	41.5 (49.0-36.0)	43.0 (49.0-37.0)	5511.00	-1.09	.28

Note. [a] Values are displayed as mean (SD). [b] Values are displayed as median (IQR). [c] T-value is displayed, because of assessment of the independent samples t-test. [d] Degrees of freedom are displayed, because of assessment of the independent samples t-test.

Linear regression analysis was done to test the influence of migraine on the cognitive test scores while adjusting for confounders. The results of linear regression analysis are displayed in Tables 5a and 5b. Model 1 tests the unadjusted influence of migraine on the test results. Model 2 corrects for the confounders ethnicity, educational level, age, BMI, sleep, depression and smoking and model 3 adds the variable HDP for adjustment. No significant differences were found between the cognitive test results of women with and without migraine. In an additional analysis, the presence of HDP was stratified by dividing the study population into three groups: a normotensive group; a group including participants with gestational hypertension or superimposed hypertension; and a group including participants with preeclampsia, superimposed preeclampsia, or HELLP syndrome. Separate linear regression analyses were performed for each group to assess whether the presence of HDP modifies the effect of migraine on the cognitive test results. These results are presented in the Appendix. Table 5A and Table 6A show the results of the cognitive tests within the normotensive group, Table 7A and Table 8A show the results of the women with gestational hypertension and superimposed hypertension, and Table 9A and Table 10A of the women with preeclampsia, superimposed preeclampsia and the HELLP syndrome. The results are all displayed across two parts due to the size of the tables. In none of the analyses, significant differences were found between the women with and without migraine.

Table 5a

First Part of the Linear Regression Results of the Cognitive Tests by Women With and Without Migraine

Cognitive tests	Model	Beta	SE	95% CI		β	*p*
				LL	UL		
15-word learning test							
Immediate recall	1	-1.17	0.95	-3.04	0.70	-.09	.22
	2	-0.27	0.94	-2.12	1.58	-.02	.77
	3	-0.27	0.94	-2.12	1.58	-.02	.77
Delayed recall	1	-0.11	0.40	-0.91	0.68	-.02	.78
	2	0.27	0.41	-0.53	1.07	.05	.51
	3	0.27	0.41	-0.53	1.07	.05	.51
Recognition	1	0.06	0.48	-0.90	1.01	.01	.91
	2	0.25	0.50	-0.75	1.24	.04	.63
	3	0.25	0.51	-0.75	1.24	.04	.63
Stroop task							
Reading subtask	1	-0.19	0.42	-1.02	0.64	-.03	.65
	2	-0.37	0.43	-1.21	0.48	-.07	.40
	3	-0.36	0.43	-1.21	0.48	-.07	.39
Color naming subtask	1	0.06	0.56	-1.04	1.15	.01	.92
	2	-0.19	0.57	-1.32	0.93	-.03	.73
	3	-0.19	0.56	-1.31	0.92	-.03	.73
Interference subtask	1	-0.35	1.18	-2.68	1.98	-.02	.77
	2	-1.32	1.17	-3.64	0.99	-.08	.26
	3	-1.32	1.17	-3.63	0.98	-.08	.26
Letter digit substitution task	1	-0.11	0.88	-1.84	1.63	-.01	.90
	2	0.52	0.89	-1.24	2.28	.05	.56
	3	0.52	0.88	-1.22	2.26	.04	.56

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. In addition, presence of HDP is added for adjustment in Model 3.

Table 5b

Second Part of the Linear Regression Results of the Cognitive Tests by Women With and Without Migraine

Cognitive tests	Model	Beta	SE	95% CI		β	*p*
				LL	UL		
Verbal fluency task							
Number of animals after 15 sec	1	0.03	0.42	-0.79	0.86	.01	.94
	2	0.04	0.43	-0.81	0.89	.01	.93
	3	0.04	0.43	-0.81	0.89	.01	.93
Total number of animals	1	-0.41	1.07	-2.53	1.70	-.03	.70
	2	-0.07	1.09	-2.22	2.07	-.01	.95
	3	-0.08	1.09	-2.22	2.07	-.01	.95
Purdue Pegboard test							
Number of pins right handed	1	-0.32	0.37	-1.05	0.41	-.06	.39
	2	-0.13	0.38	-0.88	0.61	-.03	.73
	3	-0.13	0.38	-0.88	0.61	-.03	.72
Number of pins left handed	1	0.13	0.32	-0.50	0.77	.03	.68
	2	0.23	0.34	-0.43	0.89	.05	.49
	3	0.23	0.34	-0.43	0.89	.05	.49
Number of pins with both hands	1	-0.09	0.30	-0.69	0.50	-.02	.76
	2	-0.06	0.31	-0.67	0.55	-.02	.85
	3	-0.06	0.31	-0.67	0.55	-.02	.85
Design organization test	1	-0.85	1.31	-3.44	1.74	-.05	.52
	2	-0.17	1.33	-2.79	2.45	-.01	.90
	3	-0.17	1.33	-2.80	2.45	-.01	.90

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. In addition, presence of HDP is added for adjustment in Model 3.

For the second objective, we investigated the influence of migraine on sleep quality and mental health outcomes in postpartum women within 12 months postpartum, and whether hypertensive

disorders of pregnancy modify these associations. Therefore, a linear regression analysis was performed to test for the influence of migraine on sleep quality and depression in postpartum women while adjusting for confounders. The results are presented in Table 6. Model 1 tests the unadjusted influence of migraine on the test results. Model 2 corrects for the confounders ethnicity, educational level, age, BMI, sleep, depression and smoking and model 3 adds the variable HDP for adjustment. No significant differences were found between women with and without migraine.

Table 6

Linear Regression Predicting the Effect of Migraine on Sleep and Depression by Women With and Without Migraine

				95% CI			
Questionnaire	Model	Beta	SE	LL	UL	β	*p*
Sleep questionnaire	1	0.33	0.48	-0.62	1.28	.05	.50
	2	0.16	0.49	-0.81	1.13	.02	.75
	3	0.16	0.49	-0.82	1.13	.02	.75
Depression questionnaire	1	-0.74	1.52	-3.74	2.27	-.04	.63
	2	-1.99	1.52	-4.99	1.02	-.10	.19
	3	-1.88	1.52	-4.88	1.11	-.09	.22

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI and smoking. In addition, presence of HDP is added for adjustment in Model 3.

Discussion

In this study, we investigated the effect of migraine on cognitive function, sleep quality, and mental health outcomes in women in the postpartum period up to 12 months postpartum, with further stratification for the presence of HDP. The hypotheses were generated from the understanding of the pathophysiological similarities between migraine, HDP, and these outcomes. Contrary to these hypotheses, however, no statistically significant differences were found between those who had or had not suffered from migraine. This was true both for their subjective and objective performance on cognition as well as self-reported assessments of their sleep quality and depressive symptoms. In addition, the absence of significant differences in any of the four regression models was observed with and without adjustment for the potential confounders such as ethnicity, education level, age, BMI, sleep, depression, smoking, and HDP.

These findings seem to be surprising, given the expected negative impact of migraine and HDP on cognition, sleep quality, and mental well-being, based on their overlap in pathophysiology. Importantly, even after stratification for HDP, there was no significant difference between groups, implying that the interaction of both conditions did not result in extra impairment compared with those patients who did not have migraine. Moreover, the absence of differences was consistent across all cognitive domains, sleep quality, and depressive symptoms.

There are several reasons that could explain why there was no difference in cognitive function despite the presence of migraine. Migraine is distinguished by its pathophysiological mechanisms, including vascular dysfunction, inflammatory response, and hormonal disruption. These mechanisms have been linked to cognitive dysfunction outside of the postpartum phase (de Araújo et al., 2012; Lin et al., 2016; Stanyer et al., 2021). However, these mechanisms are already very active in all women postpartum even without the presence of migraine. Henry & Sherwin (2012) found that changes in hormones during the late postpartum phase have effects on cognitive processes, while Okun (2016) found that disrupted sleep negatively affects cognitive processes during this period. Hormonal fluctuations, exhaustion, and recovery processes after delivery activate some of these mechanisms. It is possible that the distinguishing effect of migraine, as described before, disappears, because the postpartum state itself is a time when these mechanisms are strained to their limits biologically.

In the same way, the lack of a significant difference in sleep quality between the two groups of women could be attributed to the predominance of the effect exerted by the postpartum state. Sleep disorders occur almost universally at this stage due to night feedings as well as hormonal changes

independent of the presence of migraine (Okun, 2016). It can be suggested that their influence is so strong that the additional factor associated with migraine is hard to identify.

Apart from sleep issues, there could be an alternative reason for the negative outcomes concerning mental well-being. Postpartum women experience mental health issues in different ways (Saharoy et al., 2023). The association between migraine and depression occurs due to the similarity of neurobiological factors like serotonin dysregulation and HPA axis imbalance (Antonijevic, 2008). In the postpartum period, these same mechanisms are already altered by hormonal withdrawal caused by childbirth in all women, which could obscure any migraine-specific contribution to depressive symptoms. This is further supported by Zhou et al. (2025), who found no causal relationship between migraine and postpartum depression.

Moreover, the timing of cognitive tests relative to the participant's migraine cycle is an important factor. It should be noted that migraine is not a stable condition, but a cyclic one, which includes several phases, namely, the ictal phase (when an attack occurs and the participant experiences such symptoms as headache, nausea, increased sensitivity to light and sound), interictal phase (the period between attacks when the person does not have any symptoms or is close to being symptom-free) and peri-ictal phase (the period just before and after an attack) (Fouto et al., 2025). According to previous research, cognitive functioning depends on the phase a patient experiences: while cognitive impairment is highest in the ictal phase, there are mild changes in the peri-ictal phase as well (de Araújo et al., 2012).

In the current research, only six participants (or 5.7% of the migraine patients) experienced their attack less than 24 hours ago. Thus, most of them were tested in the interictal phase. As described in the introduction, current research investigated the effect of migraine as a chronic condition, not an active attack on postpartum cognitive functioning. In other words, testing in the interictal phase is ecologically valid for the study's purposes. This result mirrors the functioning of cognitive abilities seen by women suffering from migraine in their day-to-day postpartum lives, and as such, can be viewed as an answer to the research question posed, namely that women suffering from migraine do not seem to suffer from additional cognitive disadvantages compared to women who do not have migraine in the first year after giving birth. Nonetheless, further research might consider the cognitive performance in relation to the different stages of migraine and thus gain a more thorough insight into the effect of migraine on cognitive functioning, and whether the acute or peri-ictal effects should be considered clinically significant.

There were no statistically significant differences found for the stratified analyses of the presence of HDP between those who had or had not suffered from migraine. This is consistent with the overall null findings, although it needs to be remembered that the statistical power in subgroups may be weaker due to their small sample sizes. The null findings are particularly remarkable for the HDP group, since the initial rationale indicated this particular combination of conditions as theoretically representing a high-risk category for reasons related to overlapping pathophysiology. Apart from the earlier mentioned explanation about potential postpartum overload, another possible mechanism that might account for the latency phenomenon involves pathophysiological changes that begin in pregnancy and extend in the years beyond delivery. In other words, persistent endothelial dysfunction and systemic inflammation characteristic of HDP continue following birth, initially subclinical, to where the vascular damage remains undetectable in terms of functional capacity during the immediate postpartum period, but eventually leads to impaired cerebral perfusion and cognitive deficits. This would be congruent with evidence suggesting that women with preeclampsia are at heightened risk of developing vascular dementia later in life (Basit et al., 2018).

Notably, no significant difference in cognition scores is found between women with and without migraine, with stratification of the presence of HDP, as earlier research led us to expect a compounding effect. Adank et al. (2021) and Mielke et al. (2023) both demonstrated that women with HDP had worse performance on cognitive functioning, and the pathophysiological overlap between HDP and migraine suggested that women with both HDP and migraine would demonstrate greater impairment in their cognitive performance. The failure to find such an effect, even after stratifying the analysis, is consistent with the inconsistencies present in the relationship between migraine and cognition. De Araújo et al. (2012) noted that one-third of studies looking at cognitive changes in patients suffering from migraine showed no difference, suggesting that cognitive impairment may only be present in those with more neurological impairments due to severe migraine. This is consistent with the current results, where migraine, by itself, does not seem to cause any detectable cognitive impairments using the neuropsychological tests used in this study.

Concerning the objective of examining the influence of migraine on sleep quality, the null results were less expected. This was based on earlier research of Lin et al. (2016) and Stanyer et al. (2021) who reported poor sleep quality among people with migraine. Heydari et al. (2025) discovered that lifetime exposure to HDP is associated with short sleep duration and sleep disturbance in midlife. The lack of a difference between groups may be explained by the fact that such associations were made among people in the non-postpartum period, whereas in the postpartum period, no migraine-specific effects were found.

Concerning the objective of examining the influence of migraine on mental health, the null effect stands in line with the findings of Zhou et al. (2025). They did not find a causal relationship between migraine and postpartum depression. However, the null finding regarding the stratification of HDP presence stands in contrast to findings made by Kurki et al. (2000) and Stern et al. (2014). These studies showed bidirectional associations between mood disorders and preeclampsia. Also studies examining the relationship between HDP and depression symptoms show more likeliness of depression symptoms in women with HDP (Strapasson et al., 2018). A possible explanation could be that during the first postpartum year, they can be too weak to occur among all mental stressors faced by women in this period (Saharoy et al., 2023).

The strength of this study is that it is nested within a prospective study with a large sample of patients from the EMC that strictly adheres to the ICHD-3 criteria for migraine diagnosis and ISSHP criteria for the hypertensive disorders of pregnancy diagnosis. Another strength of the study is the broad set of the cognitive tests applied by the researchers, including verbal memory, executive function, processing speed, verbal fluency, motor coordination, and visuospatial organization, which provides the study with measurement of a broad range of the cognitive functioning. Finally, this study addresses a gap in literature as it examines cognitive impairment during the early postpartum period in this specific population of women with and without migraine and HDP.

The results obtained in this investigation could be of practical use in clinical practice, since many women suffering from migraine, especially those having had HDP during pregnancy, usually have doubts about their cognitive functions, sleep and mood state after childbirth. Of course, such concerns could be quite natural taking into account the pathology of both conditions under consideration. However, there is no necessity to think about possible negative influence of migraine at the beginning of the postpartum period. These research results could provide clinicians with a solid background to give these patients reassuring words, that is, in the postpartum year, migraine does not cause any additional difficulties regarding cognition, sleep and psychological state compared to postpartum women in general.

Some shortcomings in this research need to be discussed. First of all, the sample of participants used by researchers could be affected by selection bias, as the group of women who took part in the cognitive tests had a higher prevalence of HDP than those who refused to participate or could not be reached. Thus, the validity and generalizability of the results could be compromised. Second, a cross-sectional design implies the inability to speak about any temporal changes. It remains unclear whether there were any differences between the groups prior to pregnancy. Third, the current study did not consider the difference between women with migraine with aura and women with migraine without

aura when analyzing their cognitive functions. Indeed, evidence indicates that these two subtypes are different in their cognitive profiles. While during the interictal stage, individuals with migraine without aura exhibit similar performances to those of control subjects without any headaches, patients with migraine with aura demonstrate poor performances when engaging in selective attention tasks (Mulder et al., 1999). Consequently, merging these two groups into one group with migraine might have led to the failure to detect such differences. Further research may use these subgroups separately, thus providing sufficient data to observe the difference between their cognitive functions. Lastly, an important discrepancy in the level of education existed between groups, whereby women with migraine (31.8%) were more likely to have lower education than women who did not suffer from migraine (12.4%). It is an interesting clinical observation on its own as it could be pointing to socio-economic patterns in the prevalence of migraine or healthcare access. Even though the variable was statistically controlled for using regression models in which the level of education was used as a confounder, confounder adjustment cannot fully replace for having similar groups. Future research would benefit from using matched groups regarding the level of education.

Future investigations further need to focus on longitudinal approaches that allow for the observation of the evolution of cognitive changes from pre-conception to the late postpartum period, thus being able to detect change over time instead of only between-group differences at one single point in time. Larger and better-balanced samples along with better-balanced groups concerning the participants' education level would improve the strength of the causal inferences. More advanced techniques, either neuroimaging measures or cognitive tests tailored specifically to detecting mild impairments related to interictal migraine, may produce more accurate results.

In summary, there were no significant relationships identified between migraine and cognitive function, sleep quality, or depression in the first year postpartum among women regardless of whether or not HDP was present. While these results are in contrast with the theoretical expectations based on the physiological similarities of migraine and HDP, these findings indicate that the condition of migraine as a chronic state does not add to the burden already experienced by women during the postpartum period, beyond the challenges inherent therein. In a practical sense, the findings of this study offer solid ground on which clinicians can support and reassure their female patients with migraine, particularly those who had experienced HDP, regarding lack of negative impact of the disorder on cognitive ability, quality of sleep, or well-being in the first postpartum year.

References

Abbasi, M., Rasoal, D., Kharaghani, R., Khanjari, Z., Barati, Z., Hosseinkhani, A., Ahmadnia, E., & Haseli, A. (2024). Association between sleep disorders and preeclampsia: a systematic review and meta-analysis. *The Journal of Maternal-Fetal & Neonatal Medicine : The Official Journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstetricians*, *37*(1), 2419383. https://doi.org/10.1080/14767058.2024.2419383

Adank, M. C., Hussainali, R. F., Oosterveer, L. C., Ikram, M. A., Steegers, E. A. P., Miller, E. C., & Schalekamp-Timmermans, S. (2021). Hypertensive Disorders of Pregnancy and Cognitive Impairment: A Prospective Cohort Study. *Neurology, 96*(5), e709–e718. https://doi.org/10.1212/WNL.0000000000011363

Antonijevic I. (2008). HPA axis and sleep: identifying subtypes of major depression. *Stress (Amsterdam, Netherlands)*, *11*(1), 15–27. https://doi.org/10.1080/10253890701378967

de Araújo, C. M., Barbosa, I. G., Lemos, S. M. A., Domingues, R. B., & Teixeira, A. L. (2012). Cognitive impairment in migraine: A systematic review. *Dementia & Neuropsychologia, 6*(2), 74–79. https://doi.org/10.1590/S1980-57642012DN06020002

Ashina M. (2020). Migraine. *The New England Journal of Medicine, 383*(19), 1866–1876. https://doi.org/10.1056/NEJMra1915327

Bao, A. M., Meynen, G., & Swaab, D. F. (2008). The stress system in depression and neurodegeneration: focus on the human hypothalamus. *Brain Research Reviews*, *57*(2), 531–553. https://doi.org/10.1016/j.brainresrev.2007.04.005

Basit, S., Wohlfahrt, J., & Boyd, H. A. (2018). Pre-eclampsia and risk of dementia later in life: nationwide cohort study. *BMJ (Clinical Research ed.)*, *363*, k4109. https://doi.org/10.1136/bmj.k4109

Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *The British Journal of Clinical Psychology*, *21*(1), 1–16. https://doi.org/10.1111/j.2044-8260.1982.tb01421.x

Cen, J., Wang, Q., Cheng, L., Gao, Q., Wang, H., & Sun, F. (2024). Global, regional, and national burden and trends of migraine among women of childbearing age from 1990 to 2021: insights from the Global Burden of Disease Study 2021. *The Journal of Headache and Pain, 25*(1), 96. https://doi.org/10.1186/s10194-024-01798-z

Deak, M. C., & Stickgold, R. (2010). Sleep and cognition. *Wiley Interdisciplinary Reviews. Cognitive Science*, 1(4), 491–500. https://doi.org/10.1002/wcs.52

van der Elst, W., van Boxtel, M. P., van Breukelen, G. J., & Jolles, J. (2005). Rey's verbal learning test: normative data for 1855 healthy participants aged 24-81 years and the influence of age, sex,

education, and mode of presentation. *Journal of the International Neuropsychological Society : JINS*, *11*(3), 290–302. https://doi.org/10.1017/S1355617705050344

van der Elst, W., van Boxtel, M. P., van Breukelen, G. J., & Jolles, J. (2006). The Letter Digit Substitution Test: normative data for 1,858 healthy participants aged 24-81 from the Maastricht Aging Study (MAAS): influence of age, education, and sex. *Journal of Clinical and Experimental Neuropsychology*, *28*(6), 998–1009. https://doi.org/10.1080/13803390591004428

Fouto, A. R., Nunes, R. G., Guadilla, I., Ruiz-Tagle, A., Esteves, I., Caetano, G., Silva, N. A., Vilela, P., Gil-Gouveia, R., & Figueiredo, P. (2025). Alterations of White Matter Microstructure in Migraine Patients Vary in the Peri-ictal Phases. *eNeuro*, *12*(1), ENEURO.0300-24.2024. https://doi.org/10.1523/ENEURO.0300-24.2024

Henry, J. F., & Sherwin, B. B. (2012). Hormones and cognitive functioning during late pregnancy and postpartum: a longitudinal study. *Behavioral Neuroscience*, *126*(1), 73–85. https://doi.org/10.1037/a0025540

Heydari, K., Rifas-Shiman, S. L., Bertisch, S. M., Klerman, E. B., Chavarro, J. E., Oken, E., & Switkowski, K. M. (2025). Lifetime history of hypertensive disorders of pregnancy is associated with shorter sleep duration and more sleep disturbance in midlife: results from the Project Viva women's health cohort. *Biology of Sex Differences*, *16*(1), 46. https://doi.org/10.1186/s13293-025-00725-4

Holland P. R. (2014). Headache and sleep: shared pathophysiological mechanisms. *Cephalalgia: An International Journal of Headache*, *34*(10), 725–744. https://doi.org/10.1177/0333102414541687

Hoogendam, Y. Y., Hofman, A., van der Geest, J. N., van der Lugt, A., & Ikram, M. A. (2014). Patterns of cognitive function in aging: the Rotterdam Study. *European Journal of Epidemiology*, *29*(2), 133–140. https://doi.org/10.1007/s10654-014-9885-4

Kaur, S., Ewing, H. T., & Warrington, J. P. (2023). Blood-Brain Barrier Dysfunction in Hypertensive Disorders of Pregnancy. *Current Hypertension Reports*, *25*(12), 463–470. https://doi.org/10.1007/s11906-023-01288-8

Khedagi, A. M., & Bello, N. A. (2021). Hypertensive Disorders of Pregnancy. *Cardiology Clinics*, *39*(1), 77–90. https://doi.org/10.1016/j.ccl.2020.09.005

Killgore, W. D., & Gogel, H. (2014). The design organization test: further demonstration of reliability and validity as a brief measure of visuospatial ability. *Applied Neuropsychology. Adult*, *21*(4), 297–309. https://doi.org/10.1080/23279095.2013.811671

Krause, D. N., Warfvinge, K., Haanes, K. A., & Edvinsson, L. (2021). Hormonal influences in migraine - interactions of oestrogen, oxytocin and CGRP. *Nature Reviews. Neurology*, *17*(10), 621–633. https://doi.org/10.1038/s41582-021-00544-2

Kurki, T., Hiilesmaa, V., Raitasalo, R., Mattila, H., & Ylikorkala, O. (2000). Depression and anxiety in early pregnancy and risk for preeclampsia. *Obstetrics and Gynecology*, *95*(4), 487–490. https://doi.org/10.1016/s0029-7844(99)00602-x

Lin, Y. K., Lin, G. Y., Lee, J. T., Lee, M. S., Tsai, C. K., Hsu, Y. W., Lin, Y. Z., Tsai, Y. C., & Yang, F. C. (2016). Associations Between Sleep Quality and Migraine Frequency: A Cross-Sectional Case-Control Study. *Medicine*, *95*(17), e3554. https://doi.org/10.1097/MD.0000000000003554

Linfield, R. H., Peretz, A. M., & Moskatel, L. S. (2025). Postpartum Depression in Patients with Chronic Migraine: A Retrospective, Observational Analysis. *Journal of Women's Health (2002)*, *34*(8), 979–984. https://doi.org/10.1089/jwh.2024.0955

Mielke, M. M., Frank, R. D., Christenson, L. R., Fields, J. A., Rocca, W. A., & Garovic, V. D. (2023). Association of Hypertensive Disorders of Pregnancy With Cognition in Later Life. *Neurology*, *100*(19), e2017–e2026. https://doi.org/10.1212/WNL.0000000000207134

Miller, E. C., Chau, K., Mammadli, G., Levine, L. D., Grobman, W. A., Wapner, R., & Bello, N. A. (2022). Migraine and adverse pregnancy outcomes: the Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-be. *American Journal of Obstetrics and Gynecology*, *227*(3), 535–536. https://doi.org/10.1016/j.ajog.2022.04.049

Moore R. Y. (2007). Suprachiasmatic nucleus in sleep-wake regulation. *Sleep Medicine*, *8 Suppl 3*, 27–33. https://doi.org/10.1016/j.sleep.2007.10.003

Mulder, E. J., Linssen, W. H., Passchier, J., Orlebeke, J. F., & de Geus, E. J. (1999). Interictal and postictal cognitive changes in migraine. *Cephalalgia : An International Journal of Headache*, *19*(6), 557–541. https://doi.org/10.1046/j.1468-2982.1999.019006557.x

Ogoh S. (2017). Relationship between cognitive function and regulation of cerebral blood flow. *The Journal of Physiological Sciences : JPS*, *67*(3), 345–351. https://doi.org/10.1007/s12576-017-0525-0

Okun M. L. (2016). Disturbed Sleep and Postpartum Depression. *Current Psychiatry Reports*, *18*(7), 66. https://doi.org/10.1007/s11920-016-0705-2

Petca, A., Miron, B. C., Pacu, I., Dumitrașcu, M. C., Mehedințu, C., Șandru, F., Petca, R. C., & Rotar, I. C. (2022). HELLP Syndrome-Holistic Insight into Pathophysiology. *Medicina (Kaunas, Lithuania)*, *58*(2), 326. https://doi.org/10.3390/medicina58020326

Saharoy, R., Potdukhe, A., Wanjari, M., & Taksande, A. B. (2023). Postpartum Depression and Maternal Care: Exploring the Complex Effects on Mothers and Infants. *Cureus*, *15*(7), e41381. https://doi.org/10.7759/cureus.41381

Sakurai, S., Shishido, E., & Horiuchi, S. (2022). Experiences of women with hypertensive disorders of pregnancy: a scoping review. *BMC Pregnancy and Childbirth*, *22*(1), 146. https://doi.org/10.1186/s12884-022-04463-y

Sánchez-Aranguren, L. C., Prada, C. E., Riaño-Medina, C. E., & Lopez, M. (2014). Endothelial dysfunction and preeclampsia: role of oxidative stress. *Frontiers in Physiology*, *5*, 372. https://doi.org/10.3389/fphys.2014.00372

Scarpina, F., & Tagini, S. (2017). The Stroop Color and Word Test. *Frontiers in Psychology*, *8*, 557. https://doi.org/10.3389/fpsyg.2017.00557

Stanyer, E. C., Creeney, H., Nesbitt, A. D., Holland, P. R., & Hoffmann, J. (2021). Subjective Sleep Quality and Sleep Architecture in Patients With Migraine: A Meta-analysis. *Neurology*, *97*(16), e1620–e1631. https://doi.org/10.1212/WNL.0000000000012701

Stern, C., Trapp, E. M., Mautner, E., Deutsch, M., Lang, U., & Cervar-Zivkovic, M. (2014). The impact of severe preeclampsia on maternal quality of life. *Quality of Life Research : An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*, *23*(3), 1019–1026. https://doi.org/10.1007/s11136-013-0525-3

Strapasson, M. R., Ferreira, C. F., & Ramos, J. G. L. (2018). Associations between postpartum depression and hypertensive disorders of pregnancy. *International Journal of Gynaecology and Obstetrics: The Official Organ of the International Federation of Gynaecology and Obstetrics*, *143*(3), 367–373. https://doi.org/10.1002/ijgo.12665

TIFFIN, J., & ASHER, E. J. (1948). The Purdue pegboard; norms and studies of reliability and validity. *The Journal of Applied Psychology*, *32*(3), 234–247. https://doi.org/10.1037/h0061266

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists*, *14*(2), 167–177.

Tomimatsu, T., Mimura, K., Matsuzaki, S., Endo, M., Kumasawa, K., & Kimura, T. (2019). Preeclampsia: Maternal Systemic Vascular Disorder Caused by Generalized Endothelial Dysfunction Due to Placental Antiangiogenic Factors. *International Journal of Molecular Sciences*, *20*(17), 4246. https://doi.org/10.3390/ijms20174246

Wallace, J. C., Kass, S. J., & Stanny, C. J. (2002). The cognitive failures questionnaire revisited: dimensions and correlates. *The Journal of General Psychology*, *129*(3), 238–256. https://doi.org/10.1080/00221300209602098

Widmer, R. J., & Lerman, A. (2014). Endothelial dysfunction and cardiovascular disease. *Global Cardiology Science & Practice*, *2014*(3), 291–308. https://doi.org/10.5339/gcsp.2014.43

Wu, X., & Jin, R. (2025). Effects of postpartum hormonal changes on the immune system and their role in recovery. *Acta Biochimica Polonica*, *72*, 14241. https://doi.org/10.3389/abp.2025.14241

Zhou, X. J., Chen, R., & Niu, Y. M. (2025). Causal Relationship Between Migraine and Postpartum Depression: A Two-Sample Bidirectional Mendelian Randomization Study. *Journal of Pain Research*, *18*, 3675–3687. https://doi.org/10.2147/JPR.S526083

Appendix

This Appendix contains additional information on criteria for the migraine diagnosis and the comparison of HDP prevalence in contacted women. Furthermore, additional tables are included containing data about the influence of migraine on cognitive test scores, while being stratified for the presence of hypertensive disorders of pregnancy.

Migraine diagnosis

According to ICHD-3 criteria, migraine without aura can be described as a recurrent headache disorder characterized by attacks lasting 4 to 72 hours. The headaches typically feature a unilateral location, pulsating quality, moderate to severe intensity, and are exacerbated by routine physical activity. They are often accompanied by nausea, as well as sensitivity to light (photophobia) and sound (phonophobia). In addition to migraine without aura, migraine with aura can be described as recurrent attacks lasting minutes, featuring fully reversible unilateral visual, sensory, or other central nervous system symptoms that typically develop gradually. These symptoms are usually followed by a headache accompanied by associated migraine features.

Table 1A

Comparison of HDP Prevalence in Contacted Women who Performed the Cognitive Tests, Active Refusers and Passive Non-participants

Presence of HDP	Enrolled participants (*N*=233)	Active refusers [a] (*n*=211)	Passive non-participants [b] (*n*=415)
Normotensive/uncomplicated pre-existing hypertension	157 (67.4)	164 (77.7)	341 (82.2)
Gestational hypertension	15 (6.4)	20 (9.5)	22 (5.3)
(Severe) preeclampsia/superimposed hypertension/preeclampsia	52 (22.3)	23 (10.9)	46 (11.1)
HELLP syndrome	9 (3.9)	4 (1.9)	6 (1.4)

Note. Values are displayed as numbers (%).
[a] This group consisted of participants of the PERFORM-study who were not interested in performing the cognitive tests. [b] This group consists of 10 women who doubted to attend the cognitive tests, 7 women who did not perform the tests due to unknown reasons and 398 women who were suitable for the tests but not contacted.

Table 2A

First Part of the Extended Version of the General Baseline Characteristics of the Study Population

Characteristics	Total (*N*=233)	Migraine (*n*=88) [a]	No migraine (*n*=137)
Pregnancy duration [c]			
Weeks	37.0 (3.6)	36.9 (3.8)	37.0 (3.6)
Days	2.8 (2.0)	2.5 (1.9)	3.0 (2.1)
Child death in current pregnancy [b]			
Yes	4 (1.7)	1 (1.1)	3 (2.2)
No	229 (98.3)	87 (98.9)	134 (97.8)
Quality of sleep [b]			
Very good	17 (7.3)	7 (8.0)	9 (6.6)
Quite good	119 (51.1)	42 (47.7)	77 (56.2)
Quite bad	53 (22.7)	21 (23.9)	32 (23.4)
Very bad	13 (5.6)	6 (6.8)	7 (5.1)
Hours of sleep per night for the past month [c]	6.6 (1.2)	6.4 (1.2)	6.7 (1.2)
Awakenings in the night (per week) [c]	8.5 (4.8)	9.1 (4.9)	8.1 (4.8)
Gestational diabetes in current pregnancy [b]	39 (16.7)	15 (17.0)	22 (16.1)
History of hypertensive disorders of pregnancy [b]	22 (9.4)	10 (11.4)	12 (8.8)
History of gestational diabetes [b]	13 (5.6)	4 (4.5)	8 (5.8)
History of cardiovascular disease [b]	43 (18.5)	20 (22.7)	23 (16.8)

Note. [a] Of the sample of participants with migraine, 61 women had migraine with aura and 27 women had migraine without aura. [b] Values are displayed as numbers (%). [c] Values are displayed as means (SD).

Table 3A

Second Part of the Extended Version of the General Baseline Characteristics of the Study Population

Characteristics	Total (*N*=233)	Migraine (*n*=88) [a]	No migraine (*n*=137)
Smoking [b]			
Current smoker	6 (2.6)	3 (3.4)	2 (1.5)
Former smoker (quit before pregnancy)	52 (22.3)	24 (27.3)	26 (19.0)
Former smoker (quit during pregnancy)	7 (3.0)	3 (3.4)	3 (2.2)
Never smoked	154 (66.1)	54 (61.4)	98 (71.5)
Alcohol use [b]			
Yes	53 (22.7)	20 (22.7)	29 (21.2)
Stopped before pregnancy	74 (31.8)	29 (33.0)	45 (32.8)
Stopped during pregnancy	15 (6.4)	3 (3.4)	11 (8.0)
No, never	77 (33.0)	32 (36.4)	44 (32.1)
Heavy alcohol drinker (>8 per week) [b]	9 (3.9)	3 (3.4)	6 (4.4)
Physical activity [c]			
Moderate	356.7 (433.5)	430.9 (557.6)	312.8 (331.2)
Heavy	63.8 (217.6)	87.9 (334.0)	46.4 (83.5)
COVID-19 infection [b]			
Ever positive tested	164 (70.4)	61 (69.4)	96 (70.0)
Current presence of symptoms	22 (9.4)	9 (10.2)	13 (9.5)

Note. [a] Of the sample of participants with migraine, 61 women had migraine with aura and 27 women had migraine without aura. [b] Values are displayed as numbers (%). [c] Values are displayed as means (SD).

Table 4A

Extended Version of the Baseline Characteristics of the Study Population at Time of Cognitive Tests

Characteristics	Total (*N*=233)	Migraine (*n*=88) [a]	No migraine (*n*=137)
Pregnant at time of cognition test [b]	4 (1.7)	3 (3.4)	1 (0.7)
Blood pressure before test [c]			
Systolic	123.9 (15.1)	124.5 (15.4)	123.5 (15.1)
Diastolic	78.5 (10.4)	79.5 (11.4)	78.0 (9.7)
Blood pressure after test [c]			
Systolic	121.1 (16.3)	122.5 (14.6)	120.2 (17.0)
Diastolic	79.8 (10.2)	80.5 (11.1)	79.5 (9.3)
Use of hormones [b]			
Contraceptive pill	34 (14.6)	14 (15.9)	20 (14.6)
Mirena spiral	20 (8.6)	8 (9.1)	12 (8.8)
Other	10 (4.3)	3 (3.4)	6 (4.4)
None	169 (72.5)	63 (71.6)	99 (72.3)
Medication use [b]			
Antimigraine drugs	5 (2.1)	5 (5.7)	0 (0.0)
Antihypertensive drugs	18 (7.7)	10 (11.4)	8 (5.8)
Cognition-affecting drugs	5 (2.1)	3 (3.4)	2 (1.5)
Psychotic drug medication	17 (7.3)	8 (9.1)	9 (6.6)
Current breastfeeding [b]	54 (23.2)	17 (19.3)	35 (25.5)
Menstruation [b]			
Yes	120 (51.5)	46 (52.3)	69 (50.4)
No, not yet	41 (17.6)	15 (17.0)	26 (19.0)
No, using hormones	59 (25.3)	25 (28.4)	32 (23.4)
Else	13 (5.6)	2 (2.3)	10 (7.3)

Note. [a] Of the sample of participants with migraine, 61 women had migraine with aura and 27 women had migraine without aura. [b] Values are displayed as numbers (%). [c] Values are displayed as means (SD).

Table 5A

First Part of the Results of the Influence of Migraine on Cognitive Test Scores for Normotensive Women and Women with Uncomplicated Pre-existing Hypertension

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
15-word learning test							
Immediate recall	1	-1.35	1.15	-3.61	0.92	-.11	.24
	2	-0.81	1.13	-3.05	1.44	-.06	.48
Delayed recall	1	-0.13	0.48	-1.08	0.82	-.02	.79
	2	0.06	0.49	-0.92	1.04	.01	.90
Recognition	1	-0.37	0.47	-1.30	0.56	-.07	.79
	2	-0.24	0.49	-1.21	0.73	-.05	.49
Stroop task							
Reading subtask	1	-0.01	0.48	-0.96	0.94	-.003	.98
	2	0.06	0.50	-0.93	1.06	.01	.90
Color naming subtask	1	0.15	0.62	-1.08	1.37	.02	.81
	2	0.09	0.64	-1.18	1.37	.01	.88
Interference subtask	1	0.12	1.32	-2.48	2.73	.01	.93
	2	0.56	1.32	-3.18	2.06	-.04	.67
Letter digit substitution task	1	-0.47	0.99	-2.44	1.49	-.04	.63
	2	-0.04	1.00	-2.02	1.93	-.004	.97

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 153 normotensive women and four women with uncomplicated pre-existing hypertension. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.

Table 6A

Second Part of the Results of the Influence of Migraine on Cognitive Test Scores for Normotensive Women and Women with Uncomplicated Pre-existing Hypertension

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
Verbal fluency task							
Number of animals after 15 sec	1	0.12	0.53	-0.92	1.16	.02	.82
	2	0.09	0.54	-0.98	1.16	.02	.87
Total number of animals	1	-1.00	1.34	-3.65	1.65	-.07	.46
	2	-0.72	1.35	-3.40	1.97	-.05	.60
Purdue Pegboard test							
Number of pins right handed	1	-0.05	0.45	-0.93	0.84	-.01	.92
	2	-0.03	0.47	-0.95	0.90	-.01	.96
Number of pins left handed	1	0.38	0.37	-0.35	1.11	.09	.31
	2	0.36	0.39	-0.41	1.14	.09	.36
Number of pins with both hands	1	-0.05	0.35	-0.75	0.65	-.01	.89
	2	-0.15	0.36	-0.86	0.56	-.04	.68
Design organization test	1	-0.68	1.65	-3.94	2.59	-.04	.68
	2	-0.07	1.61	-3.26	3.11	-.004	.96

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 153 normotensive women and four women with uncomplicated pre-existing hypertension. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.

Table 7A

First Part of the Results of the Influence of Migraine on Cognitive Test Scores for Women with Gestational Hypertension and Superimposed Hypertension

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
15-word learning test							
Immediate recall	1	0.57	2.33	-4.61	5.75	.08	.81
	2	0.40	4.71	-14.97	15.02	.003	.99
Delayed recall	1	-1.17	1.30	-4.06	1.71	-.28	.39
	2	0.19	1.23	-3.71	4.10	.05	.89
Recognition	1	0.40	0.56	-0.85	1.65	.22	.49
	2	0.01	0.45	-1.41	1.43	.01	.98
Stroop task							
Reading subtask	1	-0.50	1.47	-3.78	2.79	-.11	.74
	2	-2.42	1.57	-7.42	2.57	-.52	.22
Color naming subtask	1	-0.07	1.93	-4.36	4.22	-.01	.97
	2	-0.75	1.34	-5.01	3.52	-.12	.62
Interference subtask	1	0.55	4.46	-9.38	10.48	.04	.91
	2	-0.17	2.71	-8.80	8.46	-.01	.95
Letter digit substitution task	1	-1.51	3.68	-9.71	6.68	-.13	.69
	2	1.75	3.09	-8.09	11.59	.15	.61

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 15 women with gestational hypertension and one with superimposed hypertension. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.

Table 8A

Second Part of the Results of the Influence of Migraine on Cognitive Test Scores for Women with Gestational Hypertension and Superimposed Hypertension

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
Verbal fluency task							
Number of animals after 15 sec	1	0.77	0.90	-1.28	2.81	.27	.42
	2	0.98	1.12	-2.58	4.54	.35	.45
Total number of animals	1	3.71	3.45	-3.98	11.40	.32	.31
	2	0.30	2.51	-7.69	8.28	.03	.91
Purdue Pegboard test							
Number of pins right handed	1	-1.63	1.62	-5.24	1.98	-.30	.34
	2	0.07	1.93	-6.09	6.22	.01	.97
Number of pins left handed	1	-1.00	1.74	-4.87	2.87	-.18	.58
	2	-0.74	1.61	-5.87	4.40	-.13	.68
Number of pins with both hands	1	-0.94	1.69	-4.72	2.83	-.17	.05
	2	-0.27	2.83	-9.26	8.73	-.05	.93
Design organization test	1	-2.00	2.95	-8.58	4.58	-.21	.51
	2	-1.51	3.60	-12.97	9.96	-.16	.70

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 15 women with gestational hypertension and one with superimposed hypertension. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.

Table 9A

First Part of the Results of the Influence of Migraine on Cognitive Test Scores for Women with Preeclampsia, Superimposed Preeclampsia and the HELLP Syndrome

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
15-word learning test							
Immediate recall	1	-1.31	2.07	-5.49	2.88	-.10	.53
	2	0.34	2.09	-3.91	4.58	.03	.87
Delayed recall	1	0.38	0.87	-1.38	2.14	.07	.66
	2	1.05	0.86	-0.69	2.78	.19	.23
Recognition	1	0.98	1.46	-1.97	3.92	.10	.51
	2	0.73	1.62	-2.57	4.02	.08	.66
Stroop task							
Reading subtask	1	-0.40	0.94	-2.29	1.49	-.07	.67
	2	-0.62	0.92	-2.47	1.24	-.10	.51
Color naming subtask	1	-0.004	1.32	-2.67	2.66	.00	.997
	2	-0.26	1.39	-3.09	2.57	-.03	.86
Interference subtask	1	-2.08	2.82	-7.78	3.63	-.11	.47
	2	-4.13	2.90	-10.01	1.76	-.22	.16
Letter digit substitution task	1	1.81	1.92	-2.07	5.69	.14	.35
	2	3.01	2.05	-1.15	7.16	.24	.15

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 46 women with (severe) preeclampsia, nine with the HELLP syndrome and five with superimposed preeclampsia. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.

Table 10A

Second Part of the Results of the Influence of Migraine on Cognitive Test Scores for Women with Preeclampsia, Superimposed Preeclampsia and the HELLP Syndrome

				95% CI			
Cognitive tests	Model	Beta	SE	LL	UL	β	*p*
Verbal fluency task							
Number of animals after 15 sec	1	-0.31	0.82	-1.97	1.36	-.06	.71
	2	-0.76	0.89	-2.56	1.04	-.14	.40
Total number of animals	1	0.70	2.05	-3.43	4.83	.05	.73
	2	1.28	2.19	-3.18	5.73	.10	.56
Purdue Pegboard test							
Number of pins right handed	1	-0.56	0.74	-2.06	0.93	-.12	.45
	2	-0.04	0.74	-1.55	1.47	-.01	.96
Number of pins left handed	1	-0.26	0.65	-1.58	1.05	-.06	.69
	2	0.12	0.70	-1.31	1.55	.03	.87
Number of pins with both hands	1	-0.10	0.55	-1.21	1.02	-.03	.86
	2	0.18	0.61	-1.07	1.42	.05	.78
Design organization test	1	0.24	2.62	-5.04	5.53	.01	.93
	2	0.67	3.00	-5.43	6.77	.04	.83

Note. Model 1 is unadjusted. Model 2 is adjusted for ethnicity, educational level, age, BMI, sleep, depression and smoking. The sample consists of 46 women with (severe) preeclampsia, nine with the HELLP syndrome and five with superimposed preeclampsia. Most values are rounded to two decimals. Values <0.01 or values near 1 that could be misrepresented are shown with three decimals to preserve accuracy.