Risk Factors for Perioperative Hypothermia in Pregnant Women undergoing Cesarean Section: A Systematic Review and Meta-Analysis

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AIM: Hypothermia is one of the common complications of cesarean section, which has a serious impact on intraoperative surgical safety and postoperative recovery of pregnant women. Mitigation of the risk factors of hypothermia in pregnant women undergoing cesarean section may reduce the probability of its occurrence and improve the perioperative comfort of pregnant women. Therefore, this study systematically evaluates the influencing factors of hypothermia in patients undergoing cesarean section, aiming to provide references for the prevention of hypothermia in pregnant women undergoing cesarean section.

METHODS: A systematic search was conducted across various databases, including PubMed, Cochrane Library, Embase, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang, and Chinese Biomedical Literature databases to gather observational studies on the factors affecting hypothermia in pregnant women undergoing cesarean section. The search deadline was January 30, 2024. Two researchers independently screened literature, extracted data, evaluated quality, and crosschecked the outcomes. Meta analysis was conducted using RevMan 5.3 and Stata17.0.

RESULTS: Twelve studies were included in this review, all of which were case-control studies conducted from 2014 to 2022, encompassing a total of 5561 pregnant women. The quality of the studies included was average or above. The meta-analysis results showed that body mass index (mean difference (MD) = –1.47; 95% confidence interval (CI) [–2.84, –0.11]; $p = 0.03$), operating room temperature (odds ratio (OR) = 2.08; 95% CI [1.56, 2.76]; $p < 0.00001$), anesthesia method (OR = 1.84; 95% CI [1.40, 2.42]; $p < 0.0001$), fluid loss (MD = 160.09; 95% CI [77.31, 242.87]; $p = 0.0002$), flushing volume (MD = 66.43; 95% CI [8.46, 124.40]; $p = 0.02$), and hypothyroidism (OR = 2.29; 95% CI [1.61, 3.27]; $p < 0.00001$) were risk factors for perioperative hypothermia in pregnant women undergoing cesarean section ($p < 0.05$).

CONCLUSIONS: The occurrence of hypothermia in pregnant women during the perioperative period is influenced by factors such as low body mass index, spinal anesthesia, low operating room temperature, intraoperative fluid loss, large flushing volume, and hypothyroidism.

Keywords: cesarean section; hypothermia; shiver; risk factors; meta-analysis

Introduction

Defined as a drop of core body temperature to below 36 °C, perioperative hypothermia is one of the most common surgical complications, with an incidence rate of 44.5% [1, 2]. Extensive exposure of the abdominal cavity and significant fluid loss are the typical characteristics and outcomes of cesarean section, predisposing pregnant women undergoing the surgery to hypothermia. Studies have shown that the incidence of perioperative hypothermia in cesarean section patients can be as high as 38% to 75% [3].

Hypothermia during cesarean section can lead to decreased immunity and coagulation function, as well as increased risk of surgical site infections and cardiac events, thus predisposing patients undergoing such condition to prolonged hospital stay [4, 5]. Additionally, intraoperative shivering caused by hypothermia can increase oxygen consumption and carbon dioxide production, leading to hypoxemia, hypercapnia, and lactic acidosis, which exacerbates pain perception [6]. Furthermore, maternal hypothermia may also result in neonatal hypothermia, affecting the neonatal birth outcome, increasing the incidence rate of neonatal diseases and the neonatal mortality rate [7]. The Perioperative Hypothermia Prevention and Treatment Expert Consensus (2023 Edition) [8] provides a list of risk factors for perioperative hypothermia and recommends relevant assessments and prevention measures; however, the consensus fails to offer specific and sufficient guidance for handling pregnant women undergoing cesarean section.

Despite a plethora of published studies on the factors influencing hypothermia or shivering during cesarean section, the study results have been variable. Therefore, in this review, we systematically evaluated the influencing factors of shivering or hypothermia in pregnant women undergo-

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Table 1. Strategy of searching literature on PubMed.

Procedures	Search strategy
#1	((((Cesarean Section[Title/Abstract]) OR (Postcesarean Section[Title/Abstract])) OR (C-Section (OB(Obstetrics)[Title/Abstract]))) OR (Abdominal Delivery[Title/Abstract])
#2	((hypothermia[Title/Abstract]) OR (Accidental Hypothermia[Title/Abstract])) OR (Shivering[Title/Abstract])
#3	((((factor[Title/Abstract]) OR (risk factor[Title/Abstract])) OR (predict[Title/Abstract])) OR (impact[Title/Abstract])) OR (influence[Title/Abstract])
#4	#1 AND #2 AND #3

stands for the full search strategy for a particular subject term. OB, obstetrics.

ing cesarean section. The results from this meta-analysis can guide the formulation of preventive measures against hypothermia in these subjects.

Materials and Methods

Inclusion and Exclusion of Literature

Inclusion Criteria

Studies fulfilling the criteria in the following were included in the analysis:

(1) Study type: The included studies can be cohort studies, case-control studies, or cross-sectional studies.

(2) Study population: The study reported on pregnant women undergoing cesarean section as the mode of delivery.

(3) Exposure factors: The study reported factors that may lead to perioperative hypothermia or shivering in pregnant women undergoing cesarean section.

(4) Outcome measures: The study measured the incidence rate of hypothermia or shivering as its outcome.

Exclusion Criteria

(1) Articles written in languages other than Chinese or English.

(2) Duplicate publications.

(3) Articles with inaccessible data or inaccurately reported data.

Search Strategy

This systematic review is reported according to PRISMA 2020 guidelines (**Supplementary Material**). The systematic search was conducted across various databases, including PubMed (https://pubmed.ncbi.nlm.nih.gov/), Cochrane Library (https://www.cochranelibrary.com/?contentLanguage=eng), Embase (https://www.embase.com/), Web of Science (https://access.clarivate.com/login?app=wos&alternative=true&shibShireURL=https:%2F%2Fwww.webofknowledge.com%2F%3Fauth%3DShibboleth&shibReturnURL=https:%2F%2Fwww.webofknowledge.com%2F%3Fapp%3Dwos%26authCode%3Dnull%26locale%3Den%26referrer%3Dmode%253DNextgen), China National Knowledge Infrastructure (CNKI) (https://www.cnki.net/), Wanfang Database (https://www.wanfangdata.com.cn/index.html), and Chinese Biomedical Literature (CBL) (http://www.sinomed.ac.cn/index.jsp) to identify observational studies focusing on the factors influencing hypothermia or shivering in pregnant women undergoing cesarean section. The search was finalized by January 30, 2024. Search terms used in this review included "cesarean section", "pregnant women", "hypothermia", and "influencing factors". Corresponding search terms in Chinese were used as search terms to find relevant literature in Chinese. Initially, the search was conducted by selecting only "Title/Abstract" as the search filter, but if the number of retrieved documents was insufficient, the search strategy would shift, selecting "full text" as the search filter. The search strategy was set to look for articles based on a combination of free words and search terms to search research and review articles. Specific search strategies are detailed in Table 1.

Literature Screening and Data Extraction

Two researchers independently conducted screening of the literature, extracted data, and crosschecked their findings. Any disagreements were resolved through discussion or by involving a third researcher. During the literature screening process, the title was initially reviewed to exclude obviously irrelevant sources, followed by a more in-depth examination of the abstract and full text prior to confirming study inclusion. The extracted information encompassed the first author, publication year, country of origin, research type, sample size, related impact, and other pertinent details.

Risk of Bias Assessment of Included Studies

Two researchers independently assessed the risk of bias in the included studies and crosschecked the results. Cohort studies and case-control studies were evaluated using the Newcastle–Ottawa Scale (NOS) as recommended by Agency for Healthcare Research and Quality (AHRQ). This scale consists of a total of 8 items; each item can be rated as either "yes" (scored as 1 or 2 points), "no" (scored as 0 points), or "unclear" (scored as 0 points), collectively contributing a total score of 9 points. A study with a total score of 0 to 3 is regarded as low-quality; 4 to 6 as medium-quality; and 7 to 9 as high-quality.

Table 2. Basic characteristics of the included literature.

Author/Publication year	Time of investigation	Country	Sample size		Risk factors	Quality scores
			Total	Hypothermia/Non-hypothermia		
Thorburn *et al.*, 2021 [9]	2017–2018	UK	226	28/198	①②③④⑤⑥⑦⑧	8
Qi *et al.*, 2022 [10]	2018–2021	China	212	89/123	①②④⑨⑫⑬	8
Wódarski *et al.*, 2020 [11]	2016–2017	Poland	155	34/121	①②③	7
Brodshaug *et al.*, 2023 [12]	2018–2019	Norway	40	13/27	①②④⑥⑧⑨	8
Desgranges *et al.*, 2017 [13]	2014–2015	France	359	81/278	①②③④⑥⑦⑧⑨⑪⑫⑬⑭⑮⑯	6
Zhang *et al.*, 2022 [14]	2018–2021	China	2808	673/2135	①②③④⑥⑦⑧⑨⑪⑫	5
Zhao, 2020 [15]	2018–2019	China	254	53/201	①⑦⑧⑨	7
Zhang *et al.*, 2023 [16]	2021–2022	China	350	73/277	①②④⑦⑪⑬⑭	8
Xie *et al.*, 2023 [17]	2020–2021	China	392	196/196	①③⑤⑥⑨⑩⑪⑬⑭⑮	9
Li *et al.*, 2023 [18]	2021–2022	China	200	106/94	①②④⑥⑧⑨⑩⑫⑮	9
Cheng *et al.*, 2023 [19]	2020–2021	China	196	98/98	①②③④⑤⑥⑨⑩⑪⑬⑭⑮⑯	8
Kong *et al.*, 2021 [20]	2018–2019	China	369	83/286	②⑥⑨⑩⑮	8

Notes: ① Age; ② Body mass index (BMI); ③ American Society of Anesthesiologists (ASA) classification; ④ Gestational age (weeks); ⑤Anesthesia; ⑥ Operating room temperature; ⑦ Duration of surgery (minutes); ⑧ Total volume of fluids infused; ⑨ Total volume of fluid loss; ⑩ Flushing volume; ⑪ Primiparity; ⑫ Type of cesarean delivery; ⑬ Hypertension; ⑭ Diabetes; ⑮ Hypothyroidism; ⑯Asthma.

Statistical Analysis

Meta-analysis was performed using RevMan 5.3 (Cochrane Collaboration, London, UK) and Stata17.0 (Stata Corp, College Station, TX, USA). Odds ratio (OR) was used as the effect index for binary categorical variables, whereas mean difference (MD) was utilized as the effect index for continuous variables. Each effect size is represented with point estimate and 95% confidence interval (CI). The heterogeneity among the results of the included studies was analyzed using the Chi-squared test (the test level was $\alpha = 0.1$), and I^2 was used to quantitatively determine the size of the heterogeneity. If there was no statistical heterogeneity among the results of each study, a fixed-effects model would be used for meta-analysis; if there was statistical heterogeneity among the results of each study, the source of heterogeneity would be further analyzed to eliminate the influence of obvious clinical heterogeneity. Finally, a random-effects model was used for meta-analysis. Obvious clinical heterogeneity was handled using methods such as subgroup analysis or sensitivity analysis, or only descriptive analysis was performed. Sensitivity analysis was performed by changing the combined-effect model of each influencing factor or removing literature with larger weights and repeating meta-analysis. Research documents describing $\geq$9 influencing factors were tested for publication bias, and Egger's value was calculated.

Results

Literature Retrieval Process and Results

During the preliminary search, a total of 1716 relevant articles were retrieved, from which 756 duplicates were removed. After excluding more articles following the perusal of titles, abstracts, and full texts, a total of 12 articles were finally included, comprising five English articles and seven Chinese articles, as shown in Fig. 1.

Basic Characteristics and Quality Assessment of the Included Literature

All 12 studies were case-control studies conducted between 2014 and 2022, encompassing a total of 5561 pregnant women. The quality of the included studies was moderate or above, as shown in Table 2 (Ref. [9–20]).

Results of Meta-Analysis

The 12 studies altogether covered 27 influencing factors, among which dosage of anesthesia, type of drug, number of blood transfusions, scarred uterus, fetal distress and so on were mentioned in only one study. Therefore, 16 influencing factors were included in this meta-analysis.

Age

Age was investigated in 10 studies, with an I^2 of 99% and $p < 0.00001$. A random-effects model was used, and the results showed no statistically significant difference in age between the two groups (MD = 0.05; 95% CI [–2.30, 2.40]; $p = 0.97$). Therefore, age is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 2).

Body Mass Index

Body mass index (BMI) was investigated in eight studies, with an I^2 of 91% and $p < 0.00001$. A random-effects model was used, and the results showed a statistically significant difference in BMI between the two groups (MD = –1.47; 95% CI [–2.84, –0.11]; $p = 0.03$). Therefore, BMI is a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 3).

American Society of Anesthesiologists (ASA) Classification

American Society of Anesthesiologists (ASA) classification was analyzed in four studies, with an I^2 of 7% and

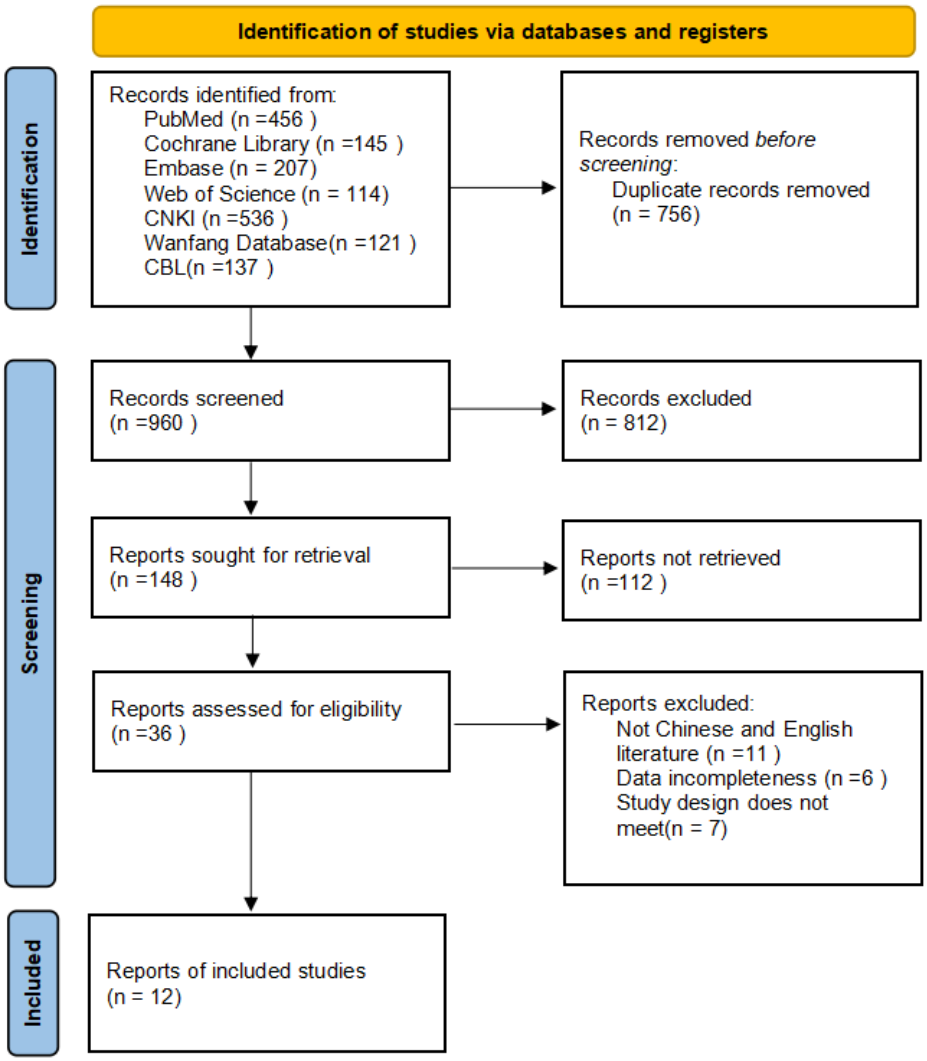

Fig. 1. Flowchart describing the retrieval, exclusion and final inclusion of articles. CNKI, China National Knowledge Infrastructure; CBL, Chinese Biomedical Literature.

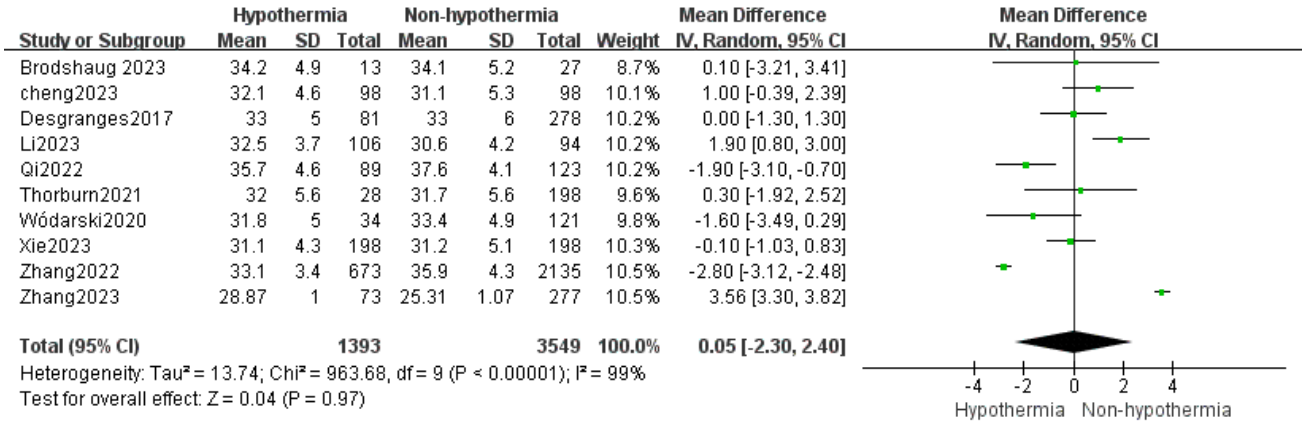

Fig. 2. Forest plot of the effect of age on perioperative hypothermia in cesarean delivery. SD, Standard Deviation; CI, confidence interval.

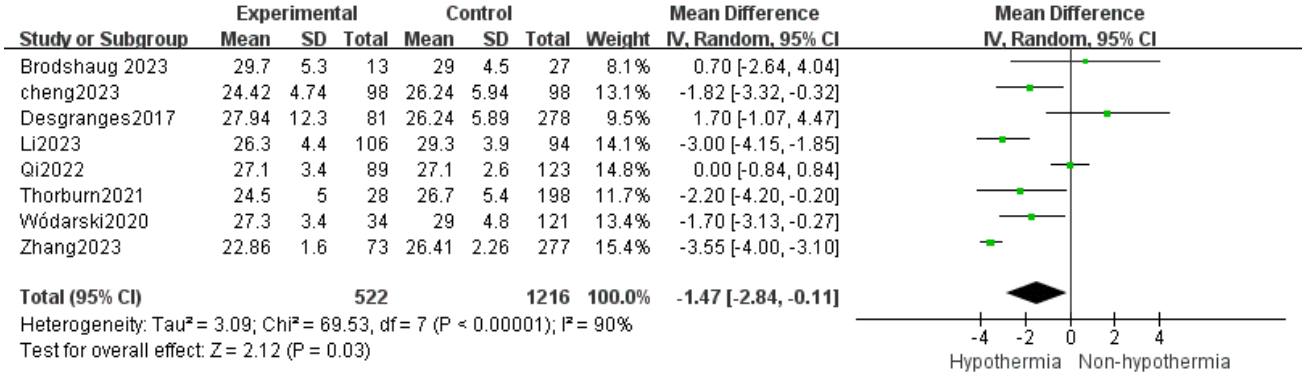

Fig. 3. Forest plot of effect of body mass index (BMI) on perioperative hypothermia in cesarean delivery.

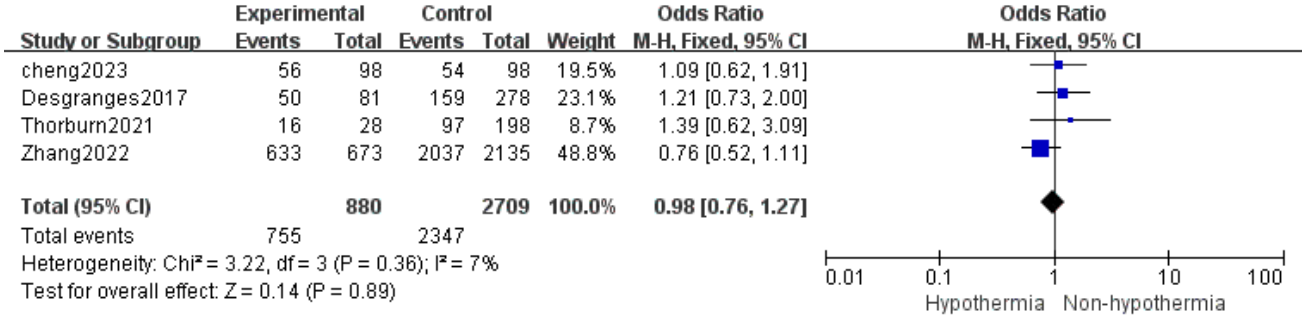

Fig. 4. Forest plot of effect of ASA classification on perioperative hypothermia in cesarean delivery.

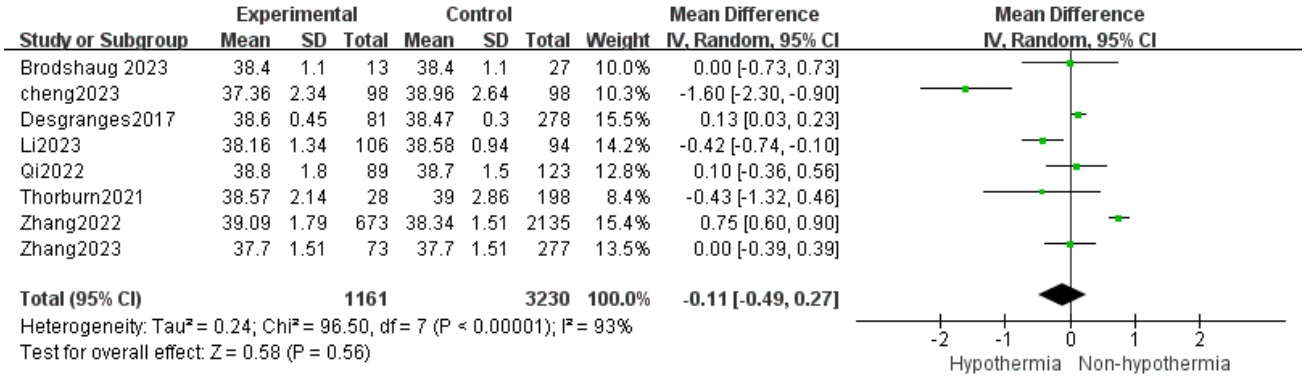

Fig. 5. Forest plot of effect of gestational age on perioperative hypothermia in cesarean delivery.

$p = 0.36$. A fixed-effects model was used, and the results showed no statistically significant difference in ASA classification between the two groups (OR = 0.98; 95% CI [0.76, 1.27]; $p = 0.89$). Therefore, preoperative ASA classification is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 4).

Gestational Age

Gestational age was analyzed in eight studies, with an I^2 of 93% and $p < 0.00001$. A random-effects model was used, and the results showed no statistically significant difference in gestational age between the two groups (MD = –0.11; 95% CI [–0.49, 0.27]; $p = 0.56$). Therefore, gestational age is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 5).

Operating Room Temperature

Operating room temperature was investigated in seven studies, with four of them studying the parameter as continuous variable, showing an I^2 of 100% and $p < 0.00001$. A random-effects model was used, and the results showed statistically significant differences between the two groups (MD = –0.93; 95% CI [–3.02, 1.15]; $p = 0.38$). Additionally, three studies investigated the parameter as binary variables (<23 °C and ≥23 °C), showing an I^2 of 0% and $p = 0.60$. A fixed-effects model was applied, revealing statisti-

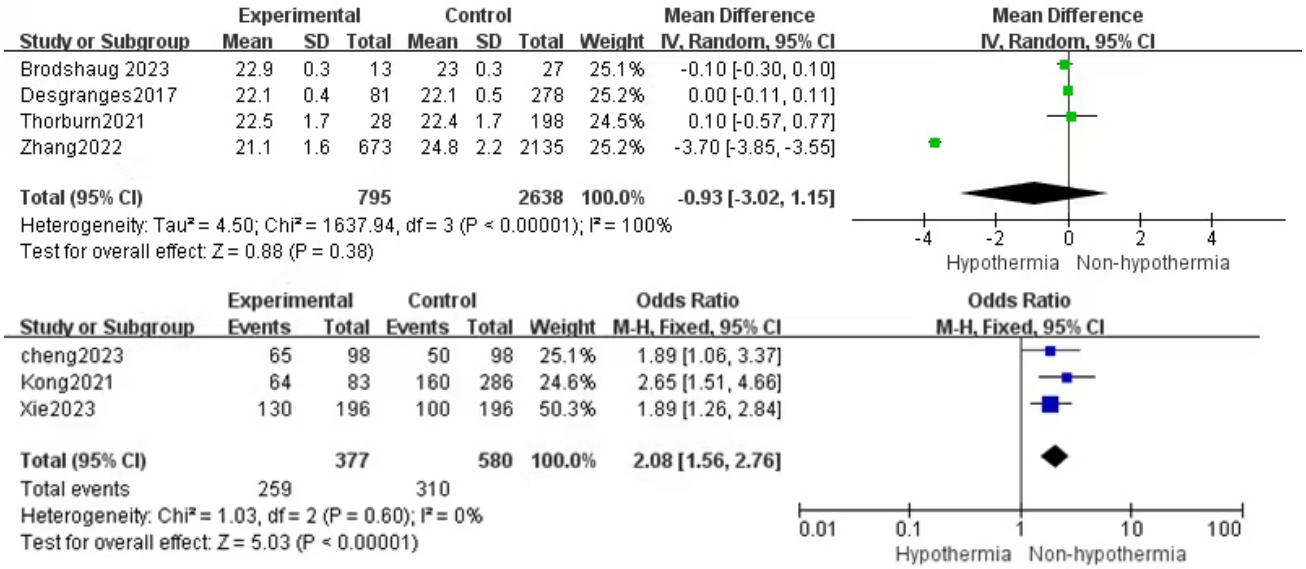

Fig. 6. Forest plots of effects of operating room temperature on perioperative hypothermia in cesarean delivery.

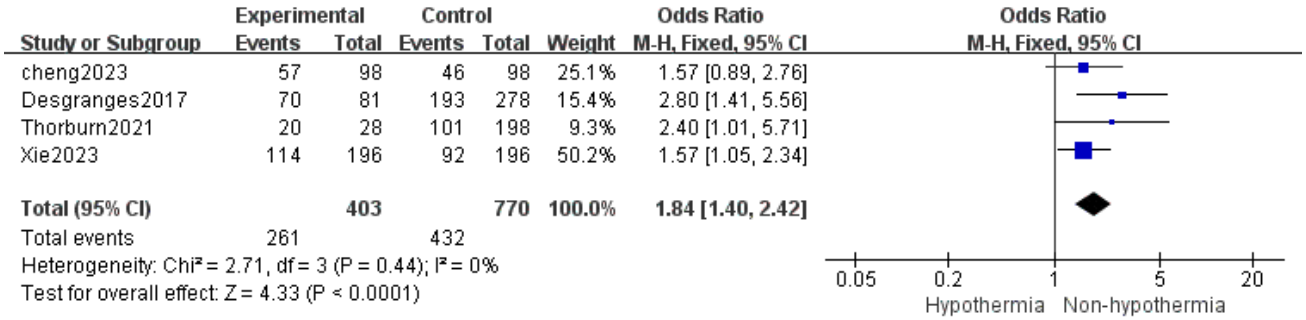

Fig. 7. Forest plot of effect of anesthesia on perioperative hypothermia in cesarean delivery.

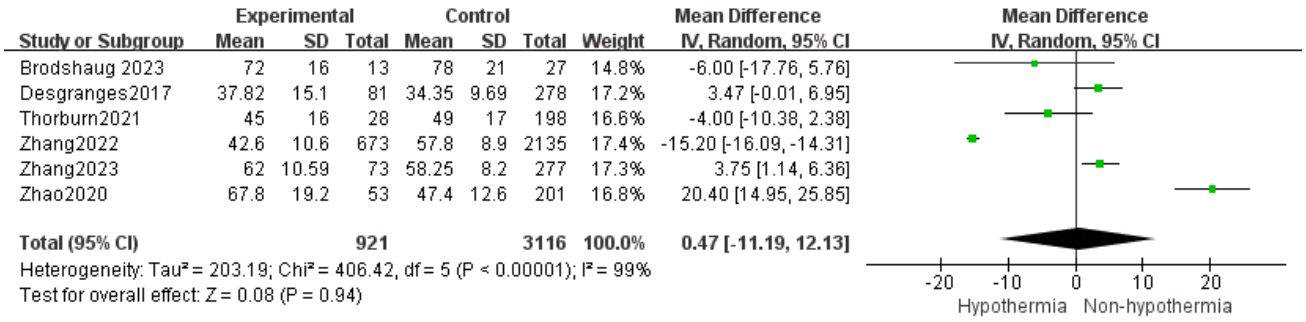

Fig. 8. Forest plot of effect of surgery duration on perioperative hypothermia in cesarean delivery.

cally significant differences between the two groups (OR = 2.08; 95% CI [1.56, 2.76]; $p < 0.00001$) (Fig. 6).

Anesthesia

In this meta-analysis, we specifically selected spinal anesthesia as the research variable. Spinal anesthesia was analyzed in four studies, with an I^2 of 0% and $p = 0.44$. A fixed-effects model was used, and the results showed statistically significant differences in spinal anesthesia between the two groups (OR = 1.84; 95% CI [1.40, 2.42]; $p < 0.0001$). Therefore, spinal anesthesia is a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 7).

Duration of Surgery

Duration of surgery was analyzed in six studies, with an I^2 of 99% and $p < 0.00001$. A random-effects model was used, and the results showed no statistically significant dif-

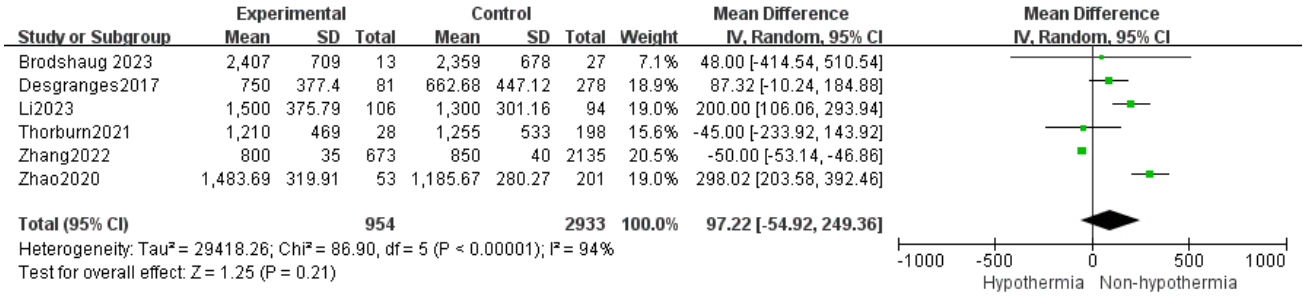

Fig. 9. Forest plot of effect of total volume of fluids infused on perioperative hypothermia in cesarean delivery.

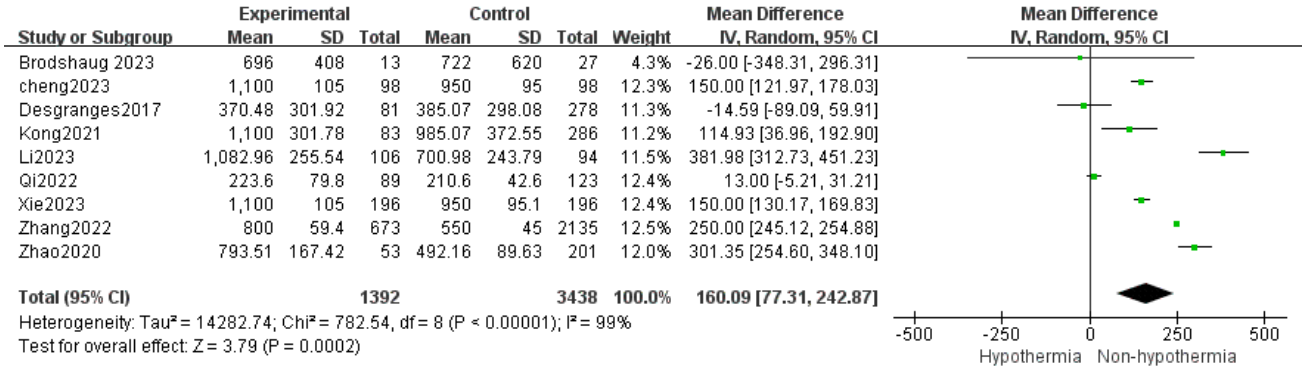

Fig. 10. Forest plot of effect of total volume of fluid loss on perioperative hypothermia in cesarean delivery.

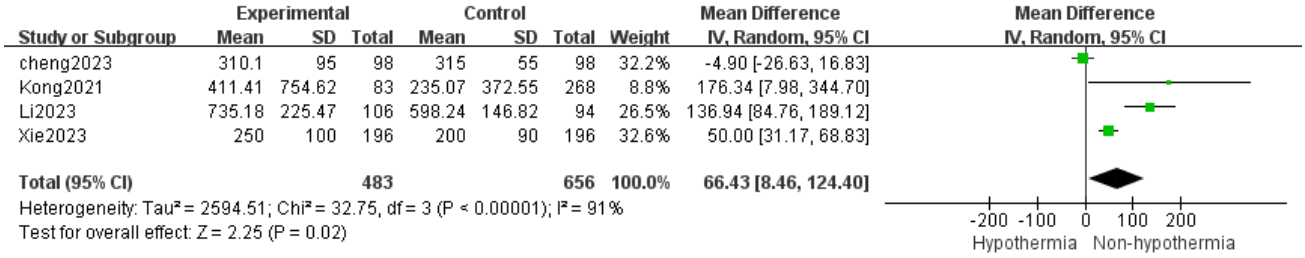

Fig. 11. Forest plot of effect of flushing volume on perioperative hypothermia in cesarean delivery.

ference in duration of surgery between the two groups (MD = 0.47; 95% CI [–11.19, 12.13]; $p = 0.94$). Therefore, the duration of surgery is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 8).

Total Volume of Fluids Infused

Of all the included studies, 6 of them had analyzed total infusion volume, with an I^2 of 94% and $p < 0.00001$. A random-effects model was used, and the results showed no statistically significant difference in total volume of fluids infused between the two groups (MD = 97.22; 95% CI [–54.92, 249.36]; $p = 0.21$). Therefore, total infusion volume is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 9).

Total Volume of Fluid Loss

Total volume of fluid loss was investigated in nine studies, with an I^2 of 99% and $p < 0.00001$. A random-effects model was used, and the results showed statistically significant differences in total volume of fluid loss between the two groups (MD = 160.09; 95% CI [77.31, 242.87]; $p = 0.0002$). Therefore, fluid loss is a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 10).

Flushing Volume

Flushing volume was analyzed in four of the 12 studies included, with an I^2 of 91% and $p < 0.00001$. A random-effects model was used, and the results showed statistically significant differences in flushing volume between the two groups (MD = 66.43; 95% CI [8.46, 124.40]; $p = 0.02$). Therefore, flushing volume is a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 11).

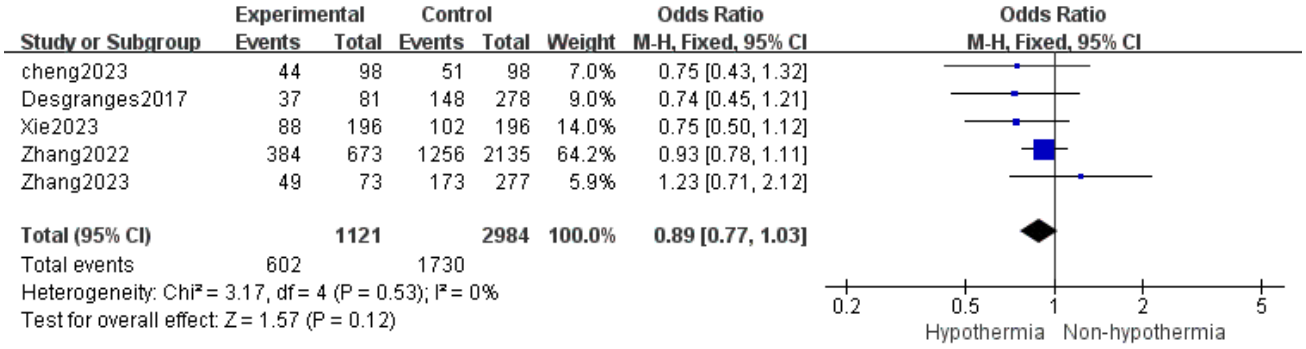

Fig. 12. Forest plot of effect of primiparity on perioperative hypothermia in cesarean delivery.

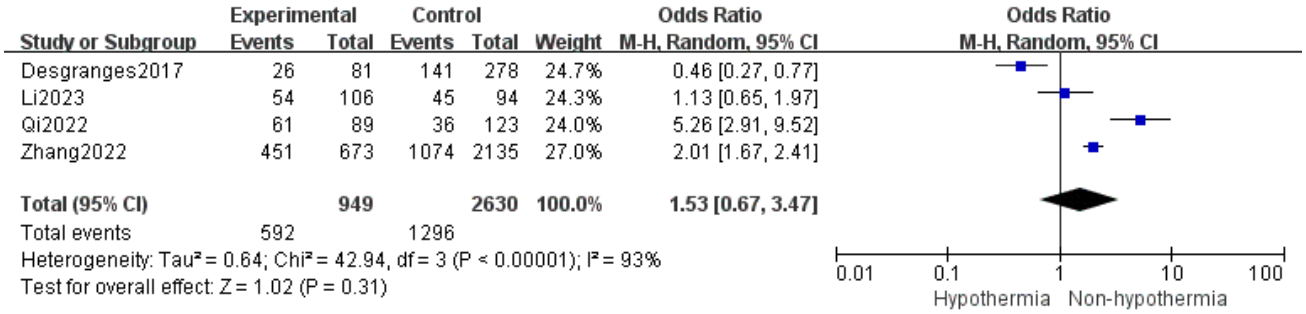

Fig. 13. Forest plot of effect of type of cesarean delivery on perioperative hypothermia in cesarean delivery.

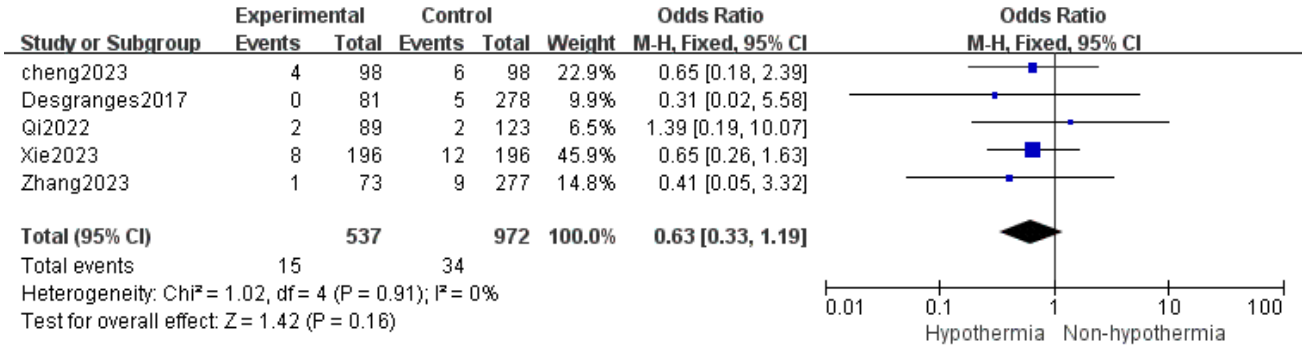

Fig. 14. Forest plot of effect of hypertension on perioperative hypothermia in cesarean delivery.

Primiparity

Primiparity was analyzed in five studies included in this meta-analysis, with an I^2 of 0% and $p = 0.53$. A fixed-effects model was used, and the results showed no statistically significant difference in primiparity between the two groups (OR = 0.89; 95% CI [0.77, 1.03]; $p = 0.12$). Therefore, primiparity is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 12).

Type of Cesarean Delivery

Cesarean delivery was investigated in four studies, with an I^2 of 93% and $p < 0.00001$. A random-effects model was used, and the results showed no statistically significant difference in the type of cesarean delivery between the two groups (OR = 1.53; 95% CI [0.67, 3.47]; $p = 0.31$). Therefore, the type of cesarean delivery is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 13).

Hypertension

Among the 12 studies included, five studies had investigated hypertension, with an I^2 of 0% and $p = 0.91$. A fixed-effects model was used, and the results showed no statistically significant difference in hypertension between the two groups (OR = 0.63; 95% CI [0.33, 1.19]; $p = 0.16$). Therefore, hypertension is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 14).

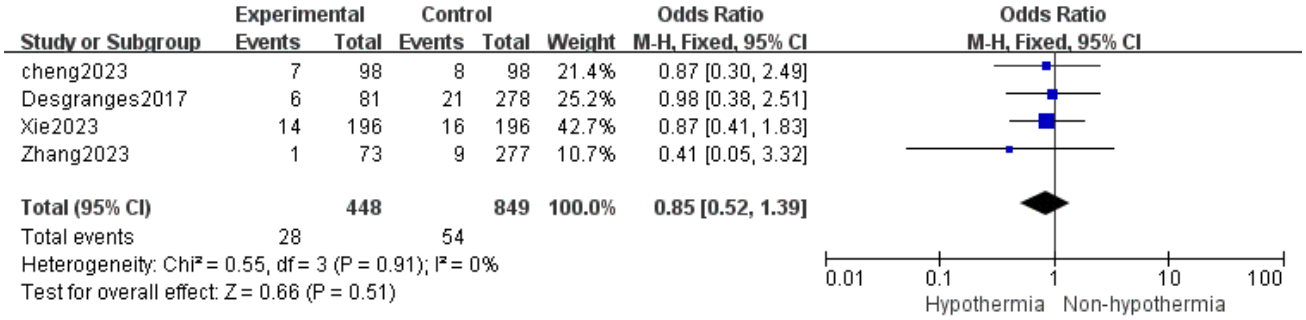

Fig. 15. Forest plot of effect of diabetes on perioperative hypothermia in cesarean delivery.

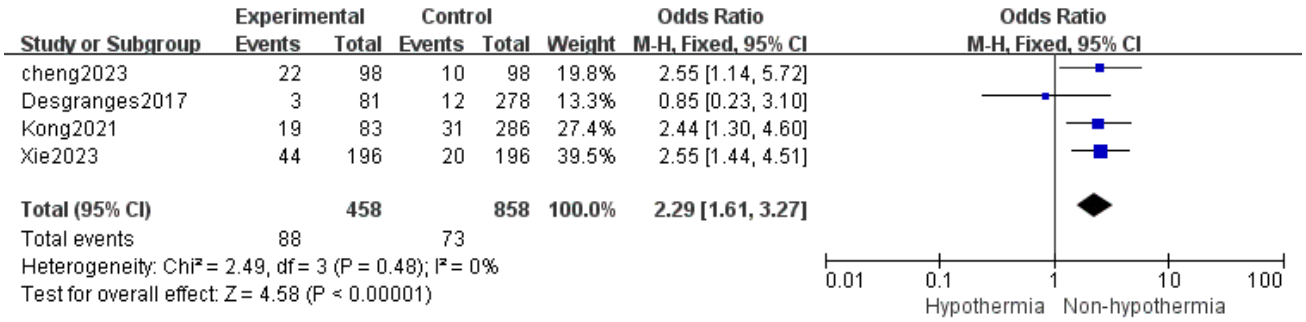

Fig. 16. Forest plot of effect of hypothyroidism on perioperative hypothermia in cesarean delivery.

Diabetes

Diabetes was analyzed in four studies, with an I^2 of 0% and $p = 0.91$. A fixed-effects model was used, and the results showed no statistically significant difference in diabetes between the two groups (OR = 0.85; 95% CI [0.52, 1.39]; $p = 0.51$). Therefore, diabetes is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 15).

Hypothyroidism

Out of the 12 studies included, four studies had investigated thyroid function, of which three focus on hypothyroidism, with an $I^2 = 0\%$ and $p = 0.48$. A fixed-effects model was used, and the results showed statistically significant differences in hypothyroidism between the two groups (OR = 2.29; 95% CI [1.61, 3.27]; $p < 0.00001$). Another study [18] compared the thyroid-stimulating hormone (TSH) levels (M [P25, P75], mIU/L) of pregnant women between the two groups, showing that the TSH levels in the hypothermic group (1.56 [1.15, 2.33]) were significantly lower than those in the non-hypothermic group (2.2 [1.63, 2.94]) ($p = 0.001$). Therefore, hypothyroidism is a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 16).

Asthma

Only two studies had investigated asthma, with an I^2 of 0% and $p = 0.84$. A fixed-effects model was used, and the results showed no statistically significant difference in asthma between the two groups (OR = 0.02; 95% CI [–0.04, 0.07]; $p = 0.56$). Therefore, asthma is not a risk factor for hypothermia in pregnant women undergoing cesarean section (Fig. 17).

Publication Bias

More than nine included articles that had investigated only two risk factors, namely age and fluid loss, were assessed for publication bias. The "scatter plots" for these two risk factors display a relatively even distribution of data points on both sides of the axis. The Egger's test results for the two factors, with $p > |t|$ values of 0.646 and 0.213, respectively, indicated no significant publication bias ($p > 0.05$) (Fig. 18).

Discussion

Effects of Inherent Factors

This study demonstrates that a pregnant woman's BMI is an important risk factor for perioperative hypothermia, with lower BMI increasing the risk for hypothermia and intraoperative shivering. It can be understood that pregnant women with higher BMI have thicker subcutaneous fat, which better retains body heat and reduces heat loss, consistent with the findings of Sari *et al.* [21]. Research has also shown that increased body fat is accompanied by physiological changes, including an increased vasoconstriction, which results in reduced heat dissipation [22]. Desgranges *et al.* [13] found that body fat of anesthetized pregnant women is significantly negatively correlated with body tempera-

Fig. 17. Forest plot of effect of asthma on perioperative hypothermia in cesarean delivery.

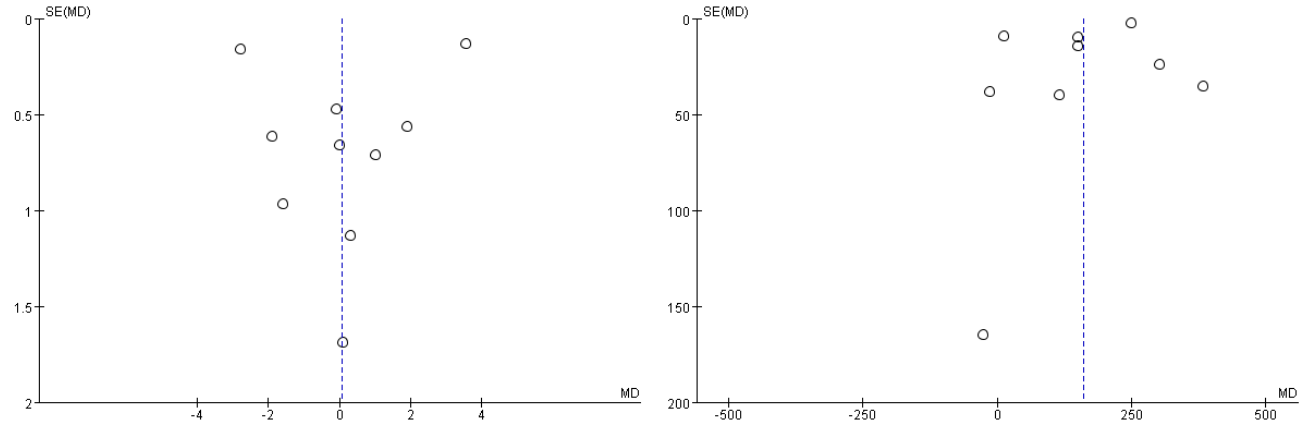

Fig. 18. Scatter plots of age (left) and fluid loss (right).

ture drop—a trend that stabilizes after one hour—consistent with the results of Groene *et al.* [23]. Additionally, the present study indicates that maternal age, ASA classification, and gestational age are not risk factors for perioperative hypothermia. According to the 2023 Expert Consensus on Prevention and Treatment of Perioperative Hypothermia in Surgical Patients, older patients are more likely to experience intraoperative hypothermia. However, most pregnant women undergoing cesarean section are in the younger age group. Therefore, this justifies the lack of correlation between age and hypothermia in this study.

Effects of Surgical Factors

Among the surgical factors, intraoperative temperature, anesthesia method, intraoperative fluid loss, and flushing volume are important risk factors for intraoperative hypothermia.

Among the seven studies on intraoperative temperature included in this analysis, four studies showed that intraoperative temperature is not an independent factor for hypothermia in pregnant women. A detailed examination of these four articles revealed that a strict control of intraoperative temperature was implemented in studies described in two of them, possibly accounting for the lack of statistical difference in the results of this analysis ($p > 0.05$). However, the remaining three studies that investigated intraoperative temperature using 23 °C as the cutoff point found that low intraoperative temperature is a risk factor for hypothermia in pregnant women undergoing cesarean section, a finding consistent with the Chinese expert consensus in 2023 [8]. A randomized controlled trial conducted by Duryea *et al.* [24] revealed that increasing the ambient temperature to 23 °C (compared to 20 °C in the control group) can reduce the likelihood of pregnant women developing hypothermia. This conclusion is consistent with the results of our meta-analysis.

In addition, our results indicated that a higher proportion of pregnant women in the hypothermia group underwent spinal anesthesia ($p < 0.05$), indicating that spinal anesthesia is an independent risk factor for hypothermia in pregnant women. Spinal anesthesia often leads to vasodilation below the sympathetic blockade level, which accelerates the loss of body heat and reduces the body's ability to respond to cold stimuli, thus leading to hypothermia [25]. Research has indicated that the decrease in core body temperature following spinal anesthesia is not due to the rate of heat loss exceeding that of heat production, but rather a result of heat redistribution from the core to the periphery [26]. This is also associated with the vasodilation of blood vessels below the blockade level after spinal anesthesia. In a network meta-analysis of different active warming measures, Zhan *et al.* [27] found that forced air warming, heated salt package (an insulation measures under the category of Chinese medicine), and electric blankets prove to be more effective in reducing the incidence of hypothermia in pregnant women. Similarly, based on their meta-analysis, Chen *et al.*

[28] found that a combination of active warming measures, merging electric blankets and liquid warming, represents an effective method for reducing intraoperative hypothermia. These results clearly showed that forced air warming and electric blankets have the greatest capacity to regulate peripheral skin temperature by stimulating skin temperature receptors, thus helping to maintain the core temperature of pregnant women.

Excessive intraoperative fluid loss and flushing volume increases the risk for hypothermia, leading to increased dissipation of maternal heat, which is gotten rid of along with the lost body fluids [29]. During cesarean delivery, the evaporation of amniotic fluid and abdominal irrigation fluid from the wet sterile drapes and the operating table, coupled with the laminar flow system in the operating room, can lead to fluctuations of intraoperative temperature. Therefore, compared to other types of surgeries, more active intraoperative warming measures are required in cesarean section procedures due to the relatively large-volume losses of fluids.

Effects of Comorbidities and Other Factors

Our results also indicate that hypothyroidism is a risk factor for hypothermia in pregnant women. The thyroid is involved in the regulation of human energy metabolism; therefore, hypothyroidism can have adverse impact on the body's heat production and dissipation functions. Giuliano and Hendricks [30] demonstrated that patients with hypothyroidism are at a higher risk for intraoperative hypothermia. Besides, hypothyroidism can increase the incidence of conditions such as preeclampsia, premature rupture of membranes, placental abruption, gestational hypertension, and diabetes in pregnant women [31].

Limitations

Several limitations of this study should be acknowledged. Firstly, the differences in baseline characteristics, such as age, surgical temperature, emergency/elective surgery, *etc.*, presented in the included studies would affect the accuracy of our analysis outputs. Secondly, the current meta-analysis did not take into consideration of the influences of factors rarely reported in the included literature, probably increasing the risk of bias. Moreover, several variables including anxiety in pregnant women which had been evaluated differently in terms of method and scale were not included in this meta-analysis; this also probably undercut the validity of the results. Lastly, compared with other equivalent meta-analyses, the sample size for this meta-analysis was relatively small. Therefore, the current set of findings still need to be further verified in large-sample epidemiological surveys investigating an expanded range of variables.

Conclusions

In summary, low BMI, spinal anesthesia, low surgical temperature, intraoperative fluid loss, high flushing volume, and hypothyroidism are the risk factors for perioperative hypothermia in pregnant women undergoing cesarean section. To enhance the survival of pregnant women during perioperative period, pregnant women associated with the above-mentioned risk factors should be given more attention, and the temperature of the operating room should be appropriately adjusted to keep them warm. Of note, early screening for thyroid function may play a significant role in improving the quality of life of pregnant women. Aside from these risk factors, the impact of other comorbidities on maternal hypothermia should not be neglected. It has been reported that promoting oxytocin secretion can reduce the incidence of hypothermia [13], possibly due to oxytocin's role in regulating temperature and metabolism [32, 33]. These results were not analyzed in this paper because of the limited number of relevant publications, as well as small sample size and methodology used in these studies, which would potentially lead to risk of bias if included in the current meta-analysis. To obtain a more complete picture regarding the risk factors for perioperative hypothermia in pregnant women, more large-sample, high-quality studies are warranted.

Availability of Data and Materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

XLW and HJQ conducted the conception and design of the article, the implementation and feasibility analysis of the study, and the revision of the paper; XLW performed the statistical processing and wrote the paper; YJZ and ZDL analyzed and interpreted the results; XQW collected and organized the data; HJQ was responsible for the quality control and proofreading of the article, and was in charge of overall responsibility for the article, supervision and management. All authors revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.3337.

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