

Supporting Information

Association between maternal vitamin D levels and risk of adverse pregnancy

outcomes: a systematic review and dose-response meta-analysis

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Short title: Vitamin D and risk of adverse pregnancy outcomes.

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Supplementary Table S1. The PRISMA 2009 checklist.

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	# 1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	# 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	# 3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	# 4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	# 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	# 4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	# 4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Table S1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	# 4, 5, Fig. 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	# 5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	# 5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	# 5, 6
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	# 5

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Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	# 5, 6
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	# 5, 6
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	# 6
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	# 6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	# 6, 7, Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	#7-9
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	#7-9
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	#7-9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	# 7-9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	#10
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	# 10-14
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	#11-12
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	# 14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	# 15

Reference: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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Supplementary Table S2. Electronic search terms and strategy.

Search terms for PubMed (19 January 2021)
#1 "Vitamin D"[MeSH] OR "Cholecalciferol"[MeSH] OR "Ergocalciferols"[MeSH]
#2 "Vitamin D"[Title/Abstract] OR "25-hydroxyvitamin D"[Title/Abstract] OR "25 oh d"[Title/Abstract] OR "1,25-dihydroxyvitamin D"[Title/Abstract] OR "cholecalciferol"[Title/Abstract] OR "ergocalciferol"[Title/Abstract]
#3 #1 OR #2
#4 "diabetes, gestational"[MeSH] OR "Pre-Eclampsia"[MeSH] OR "hypertension, pregnancy induced"[MeSH] OR "Pregnancy Complications"[MeSH]
#5 "diabetes gestational"[Title/Abstract] OR "diabetes pregnancy induced"[Title/Abstract] OR "diabetes pregnancy induced"[Title/Abstract] OR "pregnancy-induced diabetes"[Title/Abstract] OR "gestational diabetes"[Title/Abstract] OR "diabetes mellitus gestational"[Title/Abstract] OR "gestational diabetes mellitus"[Title/Abstract] OR "GDM"[Title/Abstract] OR "diabetes in pregnancy"[Title/Abstract] OR "Preeclampsia"[Title/Abstract] OR "pre-eclampsia"[Title/Abstract] OR "hypertension pregnancy induced"[Title/Abstract] OR "hypertension pregnancy induced"[Title/Abstract] OR "hypertensive disorder of pregnancy"[Title/Abstract] OR "pregnancy-induced hypertension"[Title/Abstract] OR "pregnancy-induced hypertension"[Title/Abstract] OR "pregnancy induced hypertensive disorder"[Title/Abstract] OR "pregnancy induced hypertensive disorders"[Title/Abstract] OR "PIH"[Title/Abstract] OR "HELLP"[Title/Abstract] OR "gestational hypertension"[Title/Abstract] OR "hypertension gestational"[Title/Abstract] OR "maternal hypertension"[Title/Abstract] OR "pregnancy complications"[Title/Abstract] OR "pregnancy complication"[Title/Abstract] OR "complications pregnancy"[Title/Abstract] OR "pregnancy outcomes"[Title/Abstract] OR "perinatal outcomes"[Title/Abstract] OR "maternal complications"[Title/Abstract] OR "caesarean section"[Title/Abstract] OR "caesarean delivery"[Title/Abstract] OR "caesarean section"[Title/Abstract] OR "cesarean delivery "[Title/Abstract]
#6 #4 OR #5
#7 #3 AND #6
Search terms for Embase (19 January 2021)
#1 'ergocalciferol'/exp OR 'coleciferol'/exp OR 'vitamin d'/exp
#2 'vitamin d':ab,ti OR '25-hydroxyvitamin d':ab,ti OR (25(OH)D:ab,ti) OR 1,25-dihydroxyvitamin d':ab,ti OR cholecalciferol:ab,ti OR ergocalciferol:ab,ti

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#3 #1 OR #2
#4 'pregnancy diabetes mellitus'/exp OR 'preeclampsia'/exp OR 'maternal hypertension'/exp OR 'pregnancy complication'/exp
#5 'diabetes, gestational':ab,ti OR 'diabetes, pregnancy induced':ab,ti OR 'diabetes, pregnancy-induced':ab,ti OR 'pregnancy-induced diabetes':ab,ti OR gestational diabetes':ab,ti OR 'diabetes mellitus, gestational':ab,ti OR 'gestational diabetes mellitus':ab,ti OR gdm:ab,ti OR 'diabetes in pregnancy':ab,ti OR preeclampsia:ab,ti OR 'pre eclampsia':ab,ti OR 'hypertension, pregnancy-induced':ab,ti OR 'hypertension, pregnancy induced':ab,ti OR 'hypertensive disorder of pregnancy':ab,ti OR 'hypertensive disorders of pregnancy':ab,ti OR 'pregnancy induced hypertension':ab,ti OR 'pregnancy induced hypertensive disorder':ab,ti OR 'pregnancy induced hypertensive disorders':ab,ti OR pih:ab,ti OR hellp:ab,ti OR 'gestational hypertension':ab,ti OR 'hypertension, gestational':ab,ti OR 'maternal hypertension':ab,ti OR 'pregnancy complications':ab,ti OR 'pregnancy complication':ab,ti OR 'complications, pregnancy':ab,ti OR 'pregnancy outcomes':ab,ti OR 'perinatal outcomes':ab,ti OR 'maternal complications':ab,ti OR 'cesarean delivery':ab,ti OR 'caesarean section':ab,ti OR 'caesarean delivery':ab,ti OR 'caesarean section':ab,ti
#6 #4 OR #5
#7 #3 AND #6
Search terms for Scopus (19 January 2021)
#1 ((TITLE-ABS-KEY ("vitamin D") OR TITLE-ABS-KEY ("25-hydroxyvitamin D") OR TITLE-ABS-KEY ("25(OH)D") OR TITLE-ABS-KEY ("1,25-dihydroxyvitamin D") OR TITLE-ABS-KEY ("cholecalciferol") OR TITLE-ABS-KEY ("ergocalciferol")))
#2 ((TITLE-ABS-KEY ("pregnancy induced diabetes") OR TITLE-ABS-KEY ("gestational diabetes") OR TITLE-ABS-KEY ("gestational diabetes mellitus") OR TITLE-ABS-KEY ("GDM") OR TITLE-ABS-KEY ("diabetes in pregnancy") OR TITLE-ABS-KEY ("Preeclampsia") OR TITLE-ABS-KEY ("pre-eclampsia") OR TITLE-ABS-KEY ("hypertensive disorder of pregnancy") OR TITLE-ABS-KEY ("hypertensive disorders of pregnancy") OR TITLE-ABS-KEY ("pregnancy induced hypertension") OR TITLE-ABS-KEY ("pregnancy-induced hypertension") OR TITLE-ABS-KEY ("pregnancy induced hypertensive disorder") OR TITLE-ABS-KEY ("pregnancy induced hypertensive disorders") OR TITLE-ABS-KEY ("PIH") OR TITLE-ABS-KEY ("HELLP") OR TITLE-ABS-KEY ("gestational hypertension") OR TITLE-ABS-KEY ("maternal hypertension") OR TITLE-ABS-KEY ("Pregnancy Complications") OR TITLE-ABS-KEY ("pregnancy complication") OR TITLE-ABS-KEY ("pregnancy outcomes") OR TITLE-ABS-KEY

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("perinatal outcomes") OR TITLE-ABS-KEY ("maternal complications")) OR ((TITLE-ABS-KEY (pregnan*) OR TITLE-ABS-KEY (gestation*) OR TITLE-ABS-KEY ("maternal") OR TITLE-ABS-KEY ("prenatal"))) OR ((TITLE-ABS-KEY ("caesarean section") OR TITLE-ABS-KEY ("caesarean delivery") OR TITLE-ABS-KEY ("caesarean section") OR TITLE-ABS-KEY ("cesarean delivery")))
#3 #1 AND #2
Search terms for the Web of Science (19 January 2021)
#1 TS="vitamin D" OR TS="25-hydroxyvitamin D" OR TS="25(OH)D" OR TS="1,25-dihydroxyvitamin D" OR TS="cholecalciferol" OR TS="ergocalciferol"
#2 TS="diabetes pregnancy induced" OR TS="diabetes, pregnancy induced" OR TS="diabetes, pregnancy-induced" OR TS="pregnancy-induced diabetes" OR TS="gestational diabetes" OR TS="diabetes mellitus, gestational" OR TS="gestational diabetes mellitus" OR TS="GDM" OR TS="diabetes in pregnancy" OR TS="Preeclampsia" OR TS="Pre-Eclampsia" OR TS="hypertension, pregnancy-induced" OR TS="hypertension, pregnancy induced" OR TS="hypertensive disorder of pregnancy" OR TS="hypertensive disorders of pregnancy" OR TS="pregnancy induced hypertension" OR TS="pregnancy-induced hypertension" OR TS="pregnancy induced hypertensive disorder" OR TS="pregnancy induced hypertensive disorders" OR TS="HELLP" OR TS="PIH" OR TS="gestational hypertension" OR TS="hypertension, gestational" OR TS="maternal hypertension" OR TS="Pregnancy Complications" OR TS="pregnancy complication" OR TS="complications, pregnancy" OR TS="pregnancy outcomes" OR TS="perinatal outcomes" OR TS="maternal complications" OR TS="caesarean section" OR TS="caesarean delivery" OR TS="caesarean section" OR TS="cesarean delivery"
#3 #1 AND #2

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Supplementary Table S3. List of excluded studies along with reason.

Author	Study	Reason for exclusion
Giapros, 2013 ¹	Vitamin D levels and insulin resistance in children born with severe growth restriction	No relevant outcome
Aljanahi, 2020 ²	The Effect of Dietary Intake of Vitamin D on Gestational Diabetes Mellitus	No original data
Lo, 2019 ³	Effect of Vitamin D supplementation during pregnancy on maternal and perinatal outcomes	Reviews
Loudyi, 2016 ⁴	Vitamin D status in Moroccan pregnant women and newborns: reports of 102 cases	No original data
Møller, 2012 ⁵	Effects of 25OHD concentrations on chances of pregnancy and pregnancy outcomes: A cohort study in healthy Danish women	No relevant outcome
Fatima, 2018 ⁶	Low vitamin D and risk for small for gestation age babies in gestational diabetes	No original data
Budhwar, 2020 ⁷	Altered cord serum 25-hydroxyvitamin D signaling and placental inflammation is associated with pre-term birth	No original data
Karras, 2016 ⁸	Maternal vitamin D levels during pregnancy and neonatal health: evidence to date and clinical implications	Reviews
Mumford, 2018 ⁹	Association of preconception serum 25-hydroxyvitamin D concentrations with livebirth and pregnancy loss: a prospective cohort study	No original data
Yusrawati, 2017 ¹⁰	Third trimester maternal 1,25-dihydroxyvitamin D and neonatal birth weight	No original data
Watson, 2010 ¹¹	The association of maternal diet and dietary supplement intake in pregnant New Zealand women with infant birthweight	No original data
Rezavand, 2019 ¹²	The effect of VDR gene polymorphisms and vitamin D level on blood pressure, risk of preeclampsia, gestational age, and body mass index	No original data
Dong, 2019 ¹³	The relationship between vitamin D and insulin resistance before delivery in advanced maternal age	No relevant outcome
Wierzejska, 2018 ¹⁴	Maternal and Cord Blood Vitamin D Status and Anthropometric Measurements in Term Newborns at Birth	No relevant outcome
Paxton, 2013 ¹⁵	Vitamin D and health in pregnancy, infants, children and adolescents in Australia and New Zealand: a position statement	Reviews
Dovnik, 2017 ¹⁶	Determinants of maternal vitamin D concentrations in Slovenia: A prospective observational study	No original data
Grant, 2011 ¹⁷	Adequate vitamin D during pregnancy reduces the risk of premature birth by reducing placental colonization by bacterial vaginosis species	Letter
Tamblyn, 2018 ¹⁸	Serum and urine vitamin D metabolite analysis in early preeclampsia	No original data
Hollis, 2013 ¹⁹	Vitamin D and pregnancy: Skeletal effects, nonskeletal effects, and birth outcomes	Reviews
Casey, 2018 ²⁰	Maternal vitamin D and neonatal anthropometrics and markers of neonatal glycaemia: Belfast Hyperglycemia and Adverse Pregnancy Outcome (HAPO) study	No original data
Dovnik, 2018 ²¹	The association of vitamin D levels with common pregnancy complications	Reviews
Song, 2018 ²²	High prevalence of vitamin D deficiency in pregnant women and its relationship with adverse pregnancy outcomes in Guizhou, China	No relevant outcome
Li, 2017 ²³	Women with recurrent spontaneous abortion have decreased 25(OH) vitamin D and VDR at the fetal-maternal interface	No original data
Liu, 2017 ²⁴	Investigation of the vitamin D nutritional status in women with gestational diabetes mellitus in Beijing	No original data

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Bao, 2018 ²⁵	Prepregnancy habitual intake of vitamin D from diet and supplements in relation to risk of gestational diabetes mellitus: A prospective cohort study	No relevant exposure
Bodnar, 2010 ²⁶	Vitamin D may be a link to black-white disparities in adverse birth outcomes	Reviews
Mannion, 2006 ²⁷	Association of low intake of milk and vitamin D during pregnancy with decreased birth weight	No relevant outcome
Hyde, 2017 ²⁸	Maternal Dietary Nutrient Intake During Pregnancy and Offspring Linear Growth and Bone: The Vitamin D in Pregnancy Cohort Study	No relevant outcome
Brooke, 1981 ²⁹	Intrauterine vitamin D nutrition and postnatal growth in Asian infants	Published only as abstracts
Bhowmik, 2019 ³⁰	Maternal BMI and nutritional status in early pregnancy and its impact on neonatal outcomes at birth in Bangladesh	No relevant outcome
Kabaran, 2013 ³¹	Effects of vitamins B12, folic acid, A, D, E and C on maternal and fetal health	No original data
Bond, 2008 ³²	Low Levels of Vitamin D in Women Increase the Risk of Preeclampsia	Published only as abstracts
Saha, 2020 ³³	The risk of morbidities in newborns of antenatal vitamin D supplemented gestational diabetes mellitus patients	Reviews
Aji, 2020 ³⁴	A genetic approach to study the relationship between maternal Vitamin D status and newborn anthropometry measurements: the Vitamin D pregnant mother (VDPM) cohort study	No original data
Vestergaard, 2021 ³⁵	Vitamin D insufficiency among Danish pregnant women—Prevalence and association with adverse obstetric outcomes and placental vitamin D metabolism	No original data
Ullah, 2012 ³⁶	Association of preeclampsia and eclampsia with vitamin d deficiency: Study findings from patients in a tertiary care hospital in Bangladesh	Published only as abstracts
Olmos-Ortiz, 2015 ³⁷	Regulation of calcitriol biosynthesis and activity: Focus on gestational vitamin D deficiency and adverse pregnancy outcomes	Reviews
Yoon, 2017 ³⁸	Gestational diabetes mellitus, fetal growth and vitamin D	Reviews
Thomas, 2011 ³⁹	The correlation between third-trimester maternal and newborn-serum 25-hydroxy-vitamin D in a selected South Australian group of newborn samples	No original data
Velkavrh, 2019 ⁴⁰	The Influence of Maternal Levels of Vitamin D and Adiponectin on Anthropometrical Measures and Bone Health in Offspring	No relevant outcome
McGrath, 2005 ⁴¹	Seasonal fluctuations in birth weight and neonatal limb length; does prenatal vitamin D influence neonatal size and shape?	No original data
Dabbaghmanesh, 2015 ⁴²	Comparison of 25-hydroxyvitamin D and calcium levels between preeclampsia and normal pregnant women and birth outcomes	No original data
Sonuga, 2020 ⁴³	Hypovitaminosis D Is Associated with Some Metabolic Indices in Gestational Diabetes Mellitus	No relevant outcome
Krenz-Niedbała, 2011 ⁴⁴	Season of birth and subsequent body size: the potential role of prenatal vitamin D	No relevant outcome
Sletner, 2010 ⁴⁵	Levels of 25-OH-vitamin D in early pregnancy in women from five ethnic groups with and without gestational diabetes	Published only as abstracts
Rutz, 2005 ⁴⁶	Hypovitaminosis D, insulin resistance and hypertension in pregnancy	Letter
Amirlak, 2009 ⁴⁷	Current maternal-infant micronutrient status and the effects on birth weight in the United Arab Emirates	No relevant outcome
Agudelo-Zapata, 2018 ⁴⁸	Serum 25-hydroxyvitamin D levels throughout pregnancy: A longitudinal study in healthy and preeclamptic pregnant women	No original data
Quack Lötscher, 2015 ⁴⁹	Impact of vitamin D during pregnancy on maternal health	Published only as abstracts

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Triunfo, 2017 ⁵⁰	Low maternal circulating levels of vitamin D as potential determinant in the development of gestational diabetes mellitus	Reviews
Vellinga, 2012 ⁵¹	Associations of Body Mass Index (Maternal BMI) and Gestational Diabetes Mellitus with Neonatal and Maternal Pregnancy Outcomes in a Multicentre European Database	No original data
Triunfo, 2016 ⁵²	Potential impact of maternal Vitamin D status on obstetric well-being	Reviews
Liu, 2021 ⁵³	Associations of Serum Selenium Levels in the First Trimester of Pregnancy with the Risk of Gestational Diabetes Mellitus and Preterm Birth: a Preliminary Cohort Study	No original data
Principi, 2013 ⁵⁴	Implications of maternal vitamin D deficiency for the fetus, the neonate and the young infant	Reviews
Thomsen, 2020 ⁵⁵	Vitamin D and the risk of dystocia: A case-control study	No relevant outcome
Liu, 2020 ⁵⁶	Combined Effect of Maternal Vitamin D Deficiency and Gestational Diabetes Mellitus on Trajectories of Ultrasound-Measured Fetal Growth: A Birth Cohort Study in Beijing, China	No relevant outcome
Hou, 2016 ⁵⁷	Decreased serum Vitamin D levels in early spontaneous pregnancy loss	No relevant outcome
Tapan, 2016 ⁵⁸	Assessing Vitamin D status in infants with very low birth weight	Letter
Aydeniz, 2019 ⁵⁹	The Relationship between First Trimester 25-Hydroxyvitamin D3 Levels and Second Trimester Femur Length and Their Effects on Birth Weight and Length at Birth: A Preliminary Study	No relevant outcome
Swamy, 2011 ⁶⁰	Maternal vitamin D receptor genetic variation contributes to infant birthweight among black mothers	No relevant outcome
Wibowo, 2020 ⁶¹	Vitamin D3 levels in the maternal serum, cord blood, and placenta of preeclamptic pregnant women	No relevant outcome
Horan, 2015 ⁶²	The association between maternal dietary micronutrient intake and neonatal anthropometry - Secondary analysis from the ROLO study	No original data
Kaludjerovic, 2010 ⁶³	Relationship between vitamin D during perinatal development and health	Reviews
Francis, 2018 ⁶⁴	Longitudinal Maternal Vitamin D Status during Pregnancy Is Associated with Neonatal Anthropometric Measures	No relevant outcome
Boskabadi, 2018 ⁶⁵	Serum level of vitamin D in preterm infants and its association with premature-related respiratory complications: a case-control study	No relevant outcome
Kazemi, 2009 ⁶⁶	High prevalence of vitamin D deficiency among pregnant women and their newborns in an Iranian population	No original data
Larqué, 2018 ⁶⁷	Maternal and Foetal Health Implications of Vitamin D Status during Pregnancy	Reviews
Hitman, 2012 ⁶⁸	Vitamin D, diabetic neuropathy and supplementation post-gestational diabetes	No original data
Roth, 2019 ⁶⁹	Vitamin D Supplementation in Pregnancy and Lactation and Infant Growth	Intervention studies
Hyppönen, 2011 ⁷⁰	Preventing vitamin D deficiency in pregnancy - Importance for the mother and child	Reviews
Esmeraldo, 2019 ⁷¹	Vitamin D in Term Newborns: Relation with Maternal Concentrations and Birth Weight	No original data
Boghossian, 2019 ⁷²	Longitudinal measures of maternal vitamin D and neonatal body composition	No relevant outcome
Burris, 2014 ⁷³	Vitamin D and gestational diabetes mellitus	Reviews
Orvik, 2020 ⁷⁴	Variation in plasma 25-hydroxyvitamin D2 and D3 in normal pregnancy with gestational age, sampling season, and complications: A longitudinal cohort study	No original data
Prentice, 2009 ⁷⁵	Maternal plasma 25-hydroxyvitamin D concentration and	No original data

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	birthweight, growth and bone mineral accretion of Gambian infants	
Judistiani, 2019 ⁷⁶	Association of first trimester maternal vitamin D, ferritin and hemoglobin level with third trimester fetal biometry: result from cohort study on vitamin D status and its impact during pregnancy and childhood in Indonesia	No relevant outcome
Kaptanis, 2012 ⁷⁷	Vitamin D supplementation for the prevention of pre-eclampsia? 'First do no harm'	Letter
Domaracki, 2016 ⁷⁸	Serum 25(OH) vitamin D levels in polishwomen during pregnancies complicated by hypertensive disorders and gestational diabetes	No relevant outcome
Shor, 2015 ⁷⁹	The effects of maternal vitamin D on neonatal growth parameters	No relevant outcome
Tao, 2018 ⁸⁰	Current Recommended Vitamin D Prenatal Supplementation and Fetal Growth: Results From the China-Anhui Birth Cohort Study	
Tian, 2016 ⁸¹	Maternal Serum 25-Hydroxyvitamin D Concentrations during Pregnancy and Infant Birthweight for Gestational Age: A Three-Cohort Study	No relevant outcome
Rutkowska, 2016 ⁸²	Vitamin D deficiency in women with gestational diabetes mellitus	No original data
Rudnicki, 1997 ⁸³	Effect of 1,25-dihydroxycholecalciferol on glucose metabolism in gestational diabetes mellitus	No original data
Hemalatha, 2018 ⁸⁴	Maternal Vitamin D Status and Neonatal Outcomes	Letter
Genuis, 2015 ⁸⁵	Maternal and Pediatric Health Outcomes in relation to Gestational Vitamin D Sufficiency	Reviews
Jensen, 2014 ⁸⁶	Does prenatal exposure to vitamin D-fortified margarine and milk alter birth weight? A societal experiment	No original data
Pereira-Santos, 2019 ⁸⁷	Polymorphism in the vitamin D receptor gene is associated with maternal vitamin D concentration and neonatal outcomes: A Brazilian cohort study	No relevant outcome
Bennett, 2013 ⁸⁸	Maternal Vitamin D Status in Type 1 Diabetic Pregnancy: Impact on Neonatal Vitamin D Status and Association with Maternal Glycaemic Control	No relevant outcome
Hewison, 2010 ⁸⁹	Vitamin D insufficiency and skeletal development in utero	Comment
Yakoob, 2011 ⁹⁰	Vitamin d deficiency during pregnancy and the risk of preeclampsia	Letter
Martineau, 2014 ⁹¹	Maternal vitamin D insufficiency is associated with adverse pregnancy and neonatal outcomes	Reviews
Zera, 2011 ⁹²	First and third trimester plasma vitamin D, angiogenic factors, and preeclampsia	Published only as abstracts
Burris, 2011 ⁹³	Vitamin D deficiency in pregnancy is associated with gestational diabetes	Published only as abstracts
Zazerskaya, 2016 ⁹⁴	Deficiency of vitamin D and gestational complications according to research data in Saint Petersburg, Russian Federation	Published only as abstracts
Yılmaz, 2018 ⁹⁵	Vitamin D levels in newborns and association with neonatal hypocalcemia	No relevant outcome
Yang, 2017 ⁹⁶	Influence of Vitamin D level in the second trimester of pregnancy on the complications of Chinese pregnant women and fetuses	No relevant outcome
Würtz, 2012 ⁹⁷	Vitamin D in pregnant german women and their newborns	Published only as abstracts
Wetta, 2012 ⁹⁸	Midtrimester vitamin D status is not associated with preeclampsia prior to 37 weeks	Published only as abstracts
Wetta, 2012 ⁹⁹	Midtrimester Vitamin D status is not associated with spontaneous preterm birth prior to 35 weeks	Published only as abstracts
Weiss, 2012 ¹⁰⁰	Does vitamin D given during pregnancy reduce preterm birth and pre-eclampsia?	Published only as abstracts
Wei, 2013 ¹⁰¹	Associations of plasma 25-hydroxyvitamin D levels with	Published only as

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Wei, 2016 ¹⁰²	endothelial function and preeclampsia Prenatal vitamin d status and neonatal outcomes	abstracts Published only as abstracts
Wei, 2013 ¹⁰³	Maternal obese, vitamin d status and risk of preeclampsia	Published only as abstracts
Wei, 2012 ¹⁰⁴	Vitamin D receptor gene polymorphisms and risk of preeclampsia	Published only as abstracts
Wei, 2014 ¹⁰⁵	Association of maternal vitamin D status and oxidative stress during pregnancy and risk of preeclampsia	Published only as abstracts
Wang, 2020 ¹⁰⁶	Placenta expression of vitamin D and related genes in pregnant women with gestational diabetes mellitus	No original data
Walsh, 2019 ¹⁰⁷	Avoiding maternal vitamin D deficiency may lower blood glucose in pregnancy	No relevant outcome
Walsh, 2012 ¹⁰⁸	Impact of maternal and fetal adiposity on maternal and fetal vitamin D	Published only as abstracts
von Websky, 2018 ¹⁰⁹	Impact of vitamin D on pregnancy-related disorders and on offspring outcome	Reviews
Vivanti, 2020 ¹¹⁰	Vitamin D and pregnancy outcomes: Overall results of the FEPED study	No original data
Vij, 2017 ¹¹¹	Study to find out the prevalence of Vitamin D deficiency in cord blood	Published only as abstracts
Valkama, 2018 ¹¹²	Body size modifies the relationship between maternal serum 25-hydroxyvitamin D concentrations and gestational diabetes in high-risk women	No original data
Thorp, 2011 ¹¹³	Vitamin D, fish consumption and preterm birth: Is there a link	Published only as abstracts
Stuebe, 2011 ¹¹⁴	Vitamin D-associated polymorphisms and hypertensive complications of pregnancy	Published only as abstracts
Stougaard, 2016 ¹¹⁵	Interauterin exposure to extra vitamin D from fortified margarine and later risk of preeclampsia	Published only as abstracts
Specker, 2012 ¹¹⁶	Does vitamin D during pregnancy impact offspring growth and bone?	Reviews
Skouroliakou, 2016 ¹¹⁷	Investigation of multiple factors which may contribute to Vitamin D levels of bedridden pregnant women and their preterm neonates	No relevant outcome
Singh, 2018 ¹¹⁸	Vitamin d status in preeclamptic and non preeclamptic pregnant women: Indian data	Published only as abstracts
Singh, 2011 ¹¹⁹	The relationship between cord blood vitamin D and neonatal body composition	No relevant outcome
Shibata, 2010 ¹²⁰	High prevalence of hypovitaminosis D in Japanese pregnant women with threatened premature delivery	Published only as abstracts
Naghshineh, 2016 ¹²¹	Effect of vitamin D supplementation in the reduce risk of preeclampsia in nulliparous women	Intervention studies
Mokarram, 2021 ¹²²	Study of vitamin D receptor gene methylation and the risk of gestational diabetes mellitus in Iranian pregnant women	No relevant outcome
McDonnell, 2018 ¹²³	Prenatal correction of vitamin D deficiency is associated with substantial reduction in preterm birth	Published only as abstracts
Marwaha, 2011 ¹²⁴	Vitamin D status in pregnant Indian women across trimesters and different seasons and its correlation with neonatal serum 25-hydroxyvitamin D levels	No original data
Martin, 2020 ¹²⁵	Vitamin-D dysregulation in early- and late-onset preeclampsia: A gestational-age matched study	No original data
Magnus, 2016 ¹²⁶	Association of vitamin D concentrations with gestational hypertension and pre-eclampsia: A Mendelian randomisation analysis	Published only as abstracts
Lykkedegn, 2017 ¹²⁷	Vitamin D supplementation, cord 25-hydroxyvitamin D and birth weight: Findings from the Odense Child Cohort	No relevant outcome

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Liu, 2016 ¹²⁸	Serum vitamin D levels in gestational diabetes mellitus patients and its relationship with islet cell function	Published only as abstracts
Lawlor, 2013 ¹²⁹	Association of maternal vitamin D status during pregnancy with bone-mineral content in offspring: a prospective cohort study	No relevant outcome
Larqué, 2017 ¹³⁰	Vitamin D levels during pregnancy and fetal implications	Published only as abstracts
Lanham, 2013 ¹³¹	Effect of vitamin D deficiency during pregnancy on offspring bone structure, composition and quality in later life	No relevant outcome
Lacroix, 2012 ¹³²	Lower levels of vitamin D at first trimester of pregnancy are associated with higher risk of developing gestational diabetes mellitus	Published only as abstracts
Krishnamurthy, 2012 ¹³³	Vitamin d deficiency and insufficiency; is it a risk factor for gestational diabetes and poorer glycemic control in pre existing diabetes in pregnancy? A hospital based cohort study	Published only as abstracts
Kochar, 2019 ¹³⁴	Prevalence of Vitamin D Deficiency in Cord Blood	No relevant outcome
Kim, 2014 ¹³⁵	Vitamin D deficiency is associated with higher risk of postpartum glucose intolerance in women with gestational diabetes mellitus	Published only as abstracts
Kim, 2018 ¹³⁶	A comparative analysis of maternal and fetal 25-hydroxyvitamin D in pregnant women with and without gestational diabetes mellitus	No original data
Kim, 2015 ¹³⁷	The relationship between maternal and fetal 25-hydroxy vitamin D in pregnant women with gestational diabetes mellitus	Published only as abstracts
Kılıcaslan, 2018 ¹³⁸	The effects of vitamin D supplementation during pregnancy and maternal vitamin D levels on neonatal vitamin D levels and birth parameters	No relevant outcome
Kiely, 2017 ¹³⁹	Vitamin D metabolite concentrations in umbilical cord blood serum and associations with clinical characteristics in a large prospective mother-infant cohort in Ireland	No original data
Khashan, 2013 ¹⁴⁰	The impact of vitamin d status in early pregnancy on later uteroplacental dysfunction	Published only as abstracts
Khandavalli, 2015 ¹⁴¹	Hypovitaminosis D in 1st trimester may predict gestational diabetes	Published only as abstracts
Khandavalli, 2015 ¹⁴²	Hypovitaminosis D in early pregnancy as a predictor of gestational diabetes mellitus	Published only as abstracts
Kepkep, 2020 ¹⁴³	Determination of serum vitamin D status of mothers and newborns and related outcomes	Published only as abstracts
Kenny, 2013 ¹⁴⁴	Vitamin D deficiency increases the risk of spontaneous preterm birth	Published only as abstracts
Karras, 2013 ¹⁴⁵	An observational study reveals that neonatal vitamin D is primarily determined by maternal contributions: Implications of a new assay on the roles of vitamin D forms	No original data

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Supporting Information

Supplementary Table S4. Quality assessment of cohort studies based on the Newcastle Ottawa scale.

Study	Selection				Comparability		Assessment of outcome			Total score
	a	b	c	d	e	f	g	h	i	
Chen 2020	1	1	1	1	1	1	1	1	0	8
Xu 2018	1	1	1	1	1	1	0	1	0	7
Zhu 2019	1	1	1	1	1	1	1	1	1	9
Yang 2018	1	1	1	1	0	0	0	1	0	5
Al-Ajlan 2018	0	1	1	0	1	1	1	1	1	7
Chen 2020	0	1	1	1	0	0	1	0	0	4
Gernand 2015	1	1	1	1	0	1	1	0	1	7
Hemmingway 2018	1	1	1	1	0	1	1	1	0	7
Yuan 2017	1	1	1	1	1	1	1	0	1	8
Yue 2020	1	1	1	1	1	1	1	1	0	8
Abd Aziz 2020	1	1	1	1	0	0	1	1	0	6
Dwarkanath 2019	1	1	1	1	1	1	1	1	1	9
Li 2020	1	1	1	1	1	0	1	1	0	7
Thiele 2019	1	1	1	1	0	0	1	0	0	5

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Flood-Nichols 2015	1	1	1	1	0	1	1	1	0	7
Davies-Tuck 2015	1	1	1	1	1	1	0	1	0	7
Aydogmus 2015	1	1	1	1	0	0	1	0	0	5
Arnold 2015	1	1	1	1	1	1	1	1	0	8
Alvarez-Fernandez 2015	1	1	1	1	0	0	1	1	1	7
Zhou 2014	1	1	1	1	0	0	1	1	0	6
Park 2014	1	1	1	1	1	1	1	1	0	8
Reichetzeder 2014	1	1	1	1	0	0	1	0	0	5
Lacroix 2014	1	1	1	1	0	0	1	1	0	6
Scholl 2013	1	1	1	1	1	1	1	1	0	8
Wei 2012	1	1	1	1	1	1	0	1	0	7
Scholl 2012	1	1	1	1	1	1	1	1	0	8
Perez-Ferre 2012	1	1	1	1	1	1	0	0	0	6
Fernandez-Alonso 2012	1	1	1	1	0	0	1	1	1	7
Burris 2012	1	1	1	1	1	1	1	0	0	7
Shand 2010	0	1	1	1	0	0	1	1	1	6

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Haugen 2009	1	1	1	1	1	1	1	0	0	7
Yue 2021	1	1	1	1	1	1	1	1	0	8

a. Representativeness of the exposed cohort;

b. Selection of the non-exposed cohort;

c. Ascertainment of exposure;

d. Demonstration that outcome of interest was not present at start of study;

e. Comparability of cohorts on the basis of the design or analysis (adjusted for maternal age);

f. Comparability of cohorts on the basis of the design or analysis (adjusted for maternal pre-pregnancy BMI/weight);

g. Assessment of outcome;

h. Was follow-up long enough for outcomes to occur (maternal 25(OH)D level was measured before 20 weeks);

i. Adequacy of follow-up of cohort (follow up rate $\geq 80\%$).

Supporting Information

Supplementary Table S5. Quality assessment of nested case-control studies based on the Newcastle Ottawa scale.

Study	Selection				Comparability		Assessment of exposure			Total score
	a	b	c	d	e	f	g	h	i	
Al-Shafei 2020	1	1	1	1	0	0	1	1	0	6
Xia 2018	1	1	1	1	1	1	1	1	0	8
Salakos 2021	1	1	1	1	0	0	1	1	0	6
Bozda 2020	0	1	1	1	0	0	1	1	0	5
Benachi 2019	1	1	1	1	0	0	0	1	0	5
Wen 2017	1	1	1	1	1	1	1	0	1	8
Dodds 2016	1	1	1	1	1	1	1	1	0	8
Jain 2015	1	1	1	1	0	0	1	1	0	6
Gidlof 2015	1	1	1	1	0	0	1	1	0	6
Anderson 2015	1	1	1	1	0	0	1	1	0	6
Achkar 2015	1	1	1	1	1	1	1	1	0	8
Wetta 2014	1	1	1	1	1	1	1	1	1	9
Schneuer 2014	1	1	1	1	1	0	1	1	1	8
Parlea 2012	1	1	1	1	0	0	0	1	0	5

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Baker 2012	1	1	1	1	1	1	1	1	1	0	8
Makgoba 2011	1	1	1	1	0	0	1	1	0	0	6
Azar 2011	0	1	1	1	0	0	1	1	0	0	5
Powe 2010	1	1	1	1	0	1	1	1	0	0	7
Baker 2010	1	1	1	1	1	1	1	1	0	0	8
Zhang 2008	1	1	1	1	1	1	1	1	0	0	8
Bodnar 2007	1	1	1	1	0	1	1	0	0	0	6

- a. Is the case definition adequate;
- b. Representativeness of the cases;
- c. Selection of the controls;
- d. Definitions of the controls;
- e. Comparability of cohorts on the basis of the design or analysis (adjusted for maternal age);
- f. Comparability of cohorts on the basis of the design or analysis (adjusted for maternal pre-pregnancy BMI/weight);
- g. Assessment of exposure;
- h. Same method of ascertainment for cases and controls;
- i. Non-response rate.

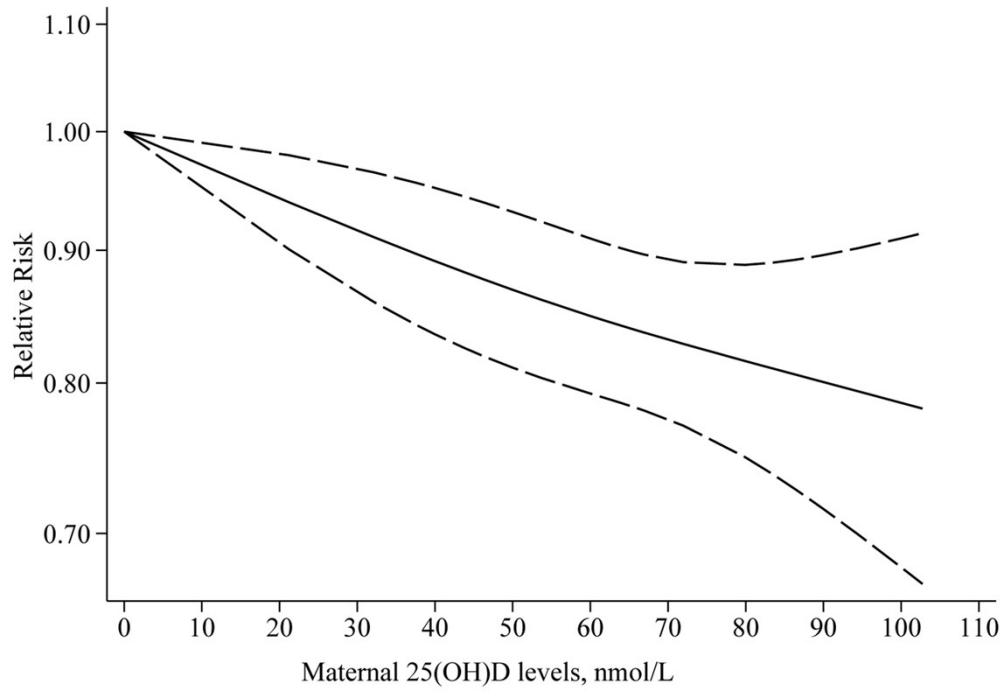
Supporting Information

Supplementary Table S6. Sensitivity analyses of maternal 25(OH)D levels and the risk of gestational diabetes mellitus.

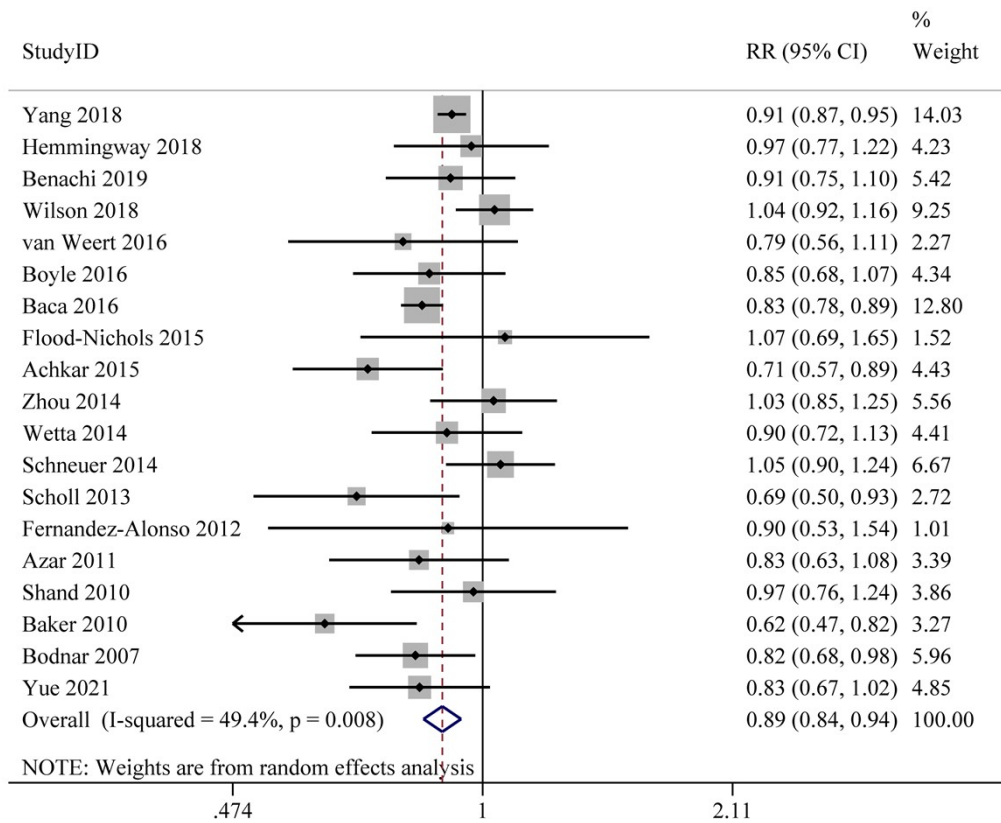
Study omitted	Pooled RR (95% CI)	I^2 (%)	$P_{\text{heterogeneity}}$
Chen 2020	0.75 (0.65, 0.81)	69.3	<0.001
Xu 2018	0.80 (0.70, 0.91)	61.8	<0.001
Zhu 2019	0.74 (0.64, 0.85)	68.9	<0.001
Yang 2018	0.75 (0.65, 0.87)	67.4	<0.001
Al-Ajlan 2018	0.76 (0.67, 0.87)	69.0	<0.001
Al-Shafei 2020	0.77 (0.67, 0.88)	68.7	<0.001
Yue 2020	0.75 (0.65, 0.86)	70.0	<0.001
Abd Aziz 2020	0.76 (0.66, 0.87)	70.0	<0.001
Dwarkanath 2019	0.77 (0.67, 0.88)	69.1	<0.001
Li 2020	0.73 (0.63, 0.85)	64.6	<0.001
Xia 2018	0.77 (0.67, 0.88)	68.9	<0.001
Shao 2020	0.74 (0.64, 0.85)	69.5	<0.001
Salakos 2021	0.75 (0.66, 0.87)	70.0	<0.001
Iqbal 2020	0.77 (0.67, 0.88)	69.1	<0.001
Bozda 2020	0.76 (0.66, 0.87)	69.8	<0.001
Griew 2019	0.75 (0.65, 0.86)	70.0	<0.001
Wilson 2018	0.76 (0.66, 0.87)	69.7	<0.001
Eggemoen 2018	0.75 (0.65, 0.86)	70.0	<0.001
Dodds 2016	0.76 (0.66, 0.87)	69.4	<0.001
Boyle 2016	0.75 (0.66, 0.86)	70.0	<0.001
Ates 2016	0.75 (0.66, 0.87)	70.0	<0.001
Rodriguez 2015	0.75 (0.65, 0.86)	69.9	<0.001
Nobles 2015	0.75 (0.65, 0.86)	69.8	<0.001
Jain 2015	0.76 (0.67, 0.87)	68.8	<0.001

Supporting Information

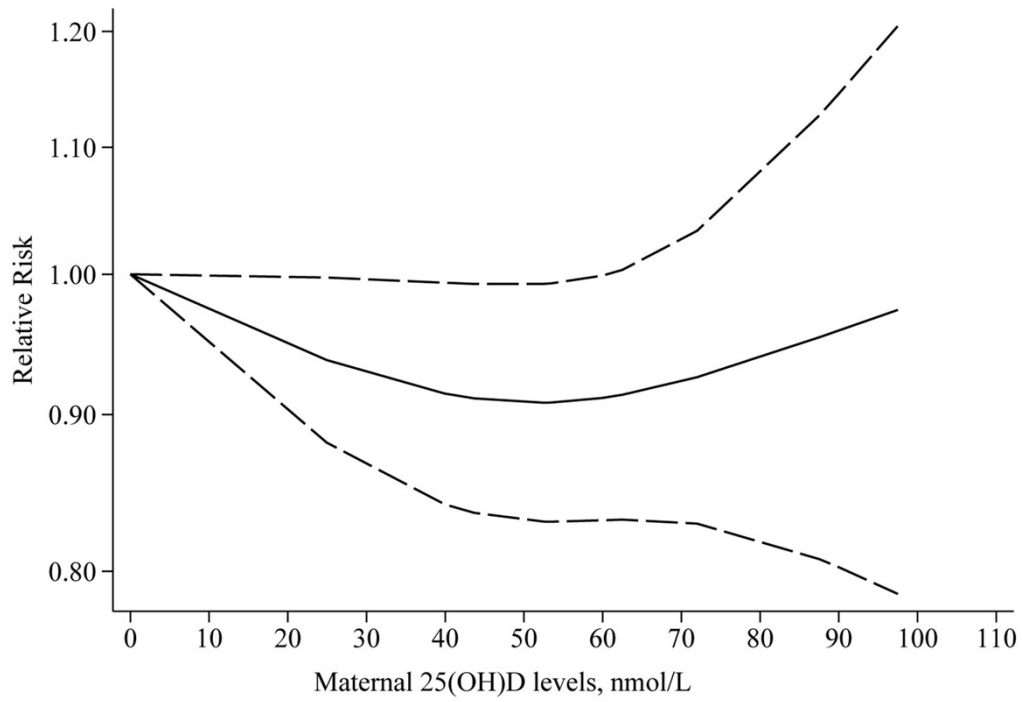
Flood-Nichols 2015	0.75 (0.66, 0.86)	69.8	<0.001
Davies-Tuck 2015	0.77 (0.67, 0.88)	68.4	<0.001
Arnold 2015	0.76 (0.66, 0.87)	69.9	<0.001
Zhou 2014	0.73 (0.64, 0.84)	65.9	<0.001
Park 2014	0.75 (0.66, 0.86)	69.4	<0.001
Schneuer 2014	0.75 (0.66, 0.87)	70.0	<0.001
Lacroix 2014	0.76 (0.67, 0.88)	69.4	<0.001
Parlea 2012	0.77 (0.67, 0.88)	69.2	<0.001
Fernandez-Alonso 2012	0.76 (0.66, 0.87)	69.9	<0.001
Baker 2012	0.75 (0.66, 0.86)	70.0	<0.001
Makgoba 2011	0.75 (0.65, 0.86)	70.0	<0.001
Zhang 2008	0.77 (0.67, 0.88)	69.3	<0.001



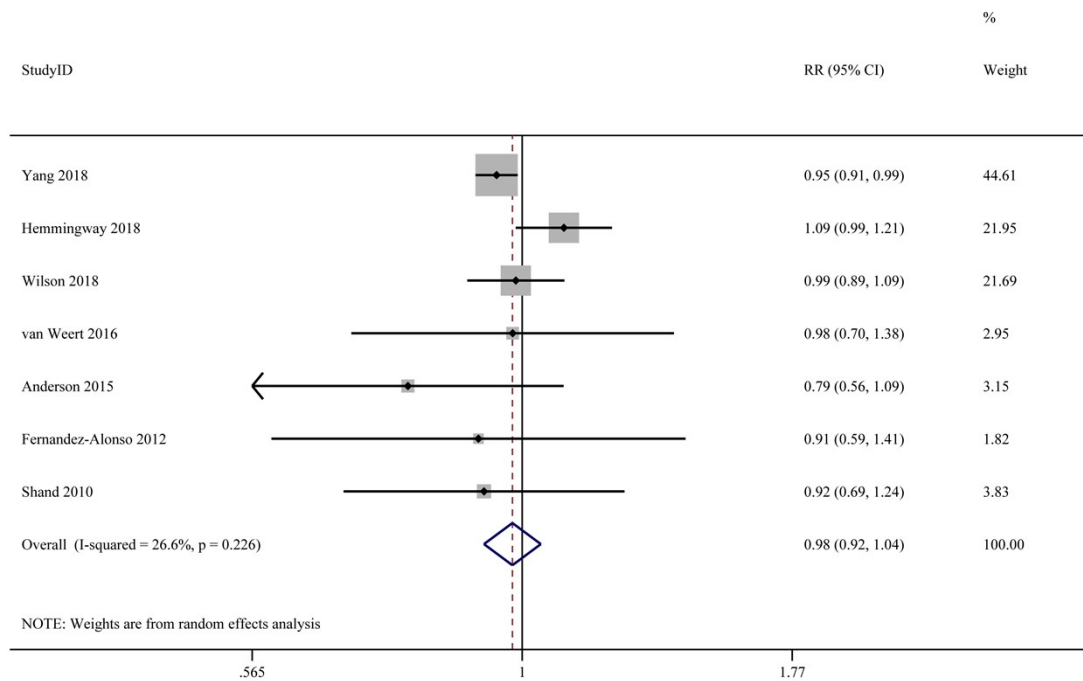
Supplementary Figure S1. Non-linear dose-response meta-analysis of maternal 25(OH)D levels and risk of GDM ($P_{\text{non-linearity}} = 0.695$). GDM, gestational diabetes mellitus.



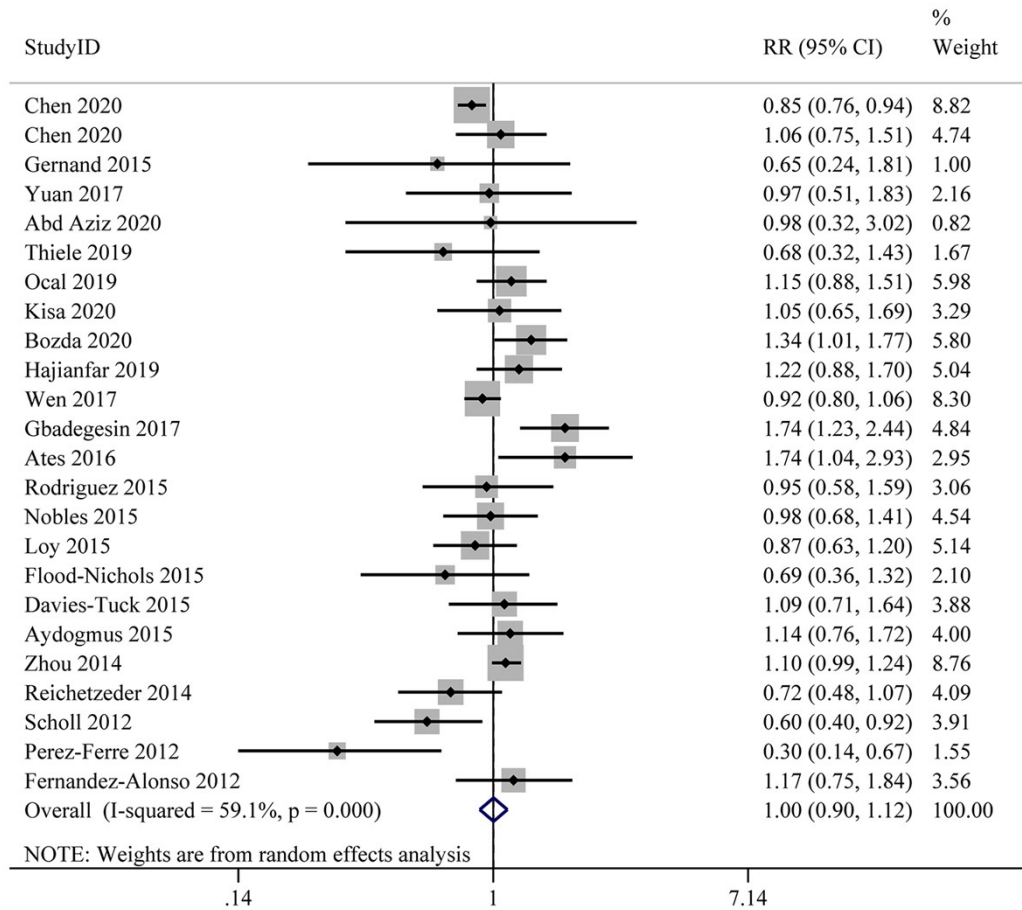
Supplementary Figure S2. Linear dose-response meta-analysis of maternal 25(OH)D levels (per 25 nmol/L increase) and risk of PE. PE, pre-eclampsia.



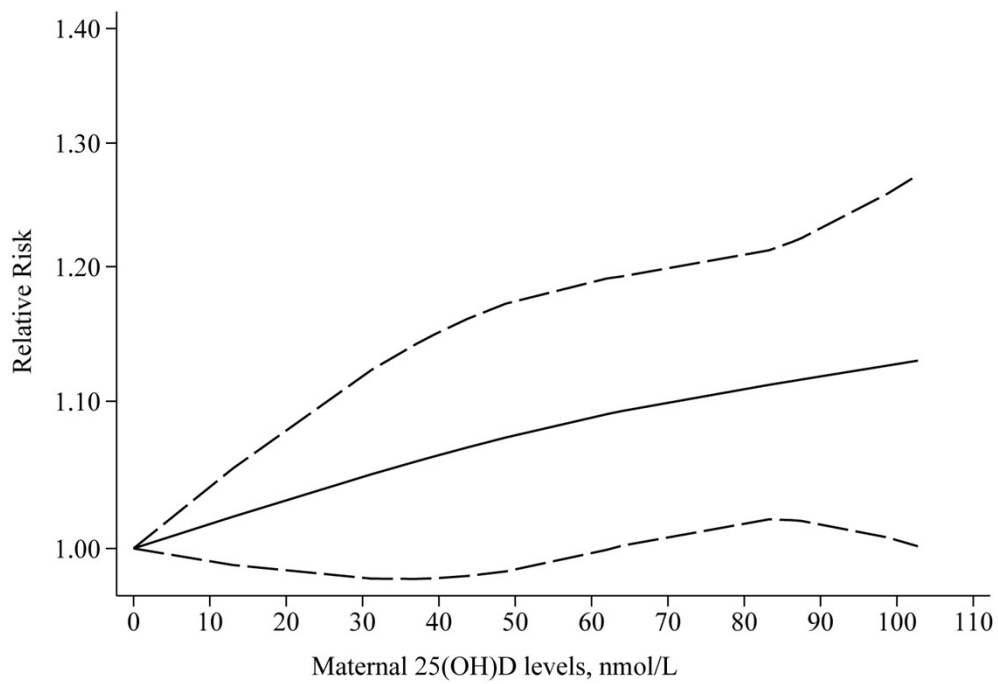
Supplementary Figure S3. Non-linear dose-response meta-analysis of maternal 25(OH)D levels and risk of GH ($P_{\text{non-linearity}} = 0.209$). GH, gestational hypertension.



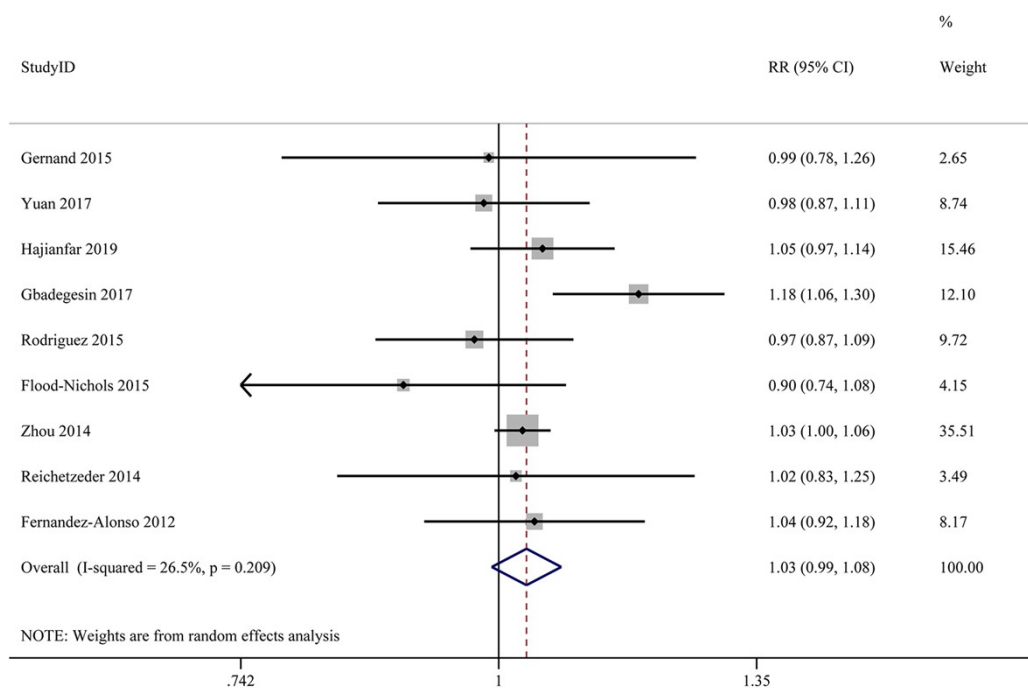
Supplementary Figure S4. Linear dose-response meta-analysis of maternal 25(OH)D levels (per 25 nmol/L increase) and risk of GH. GH, gestational hypertension.



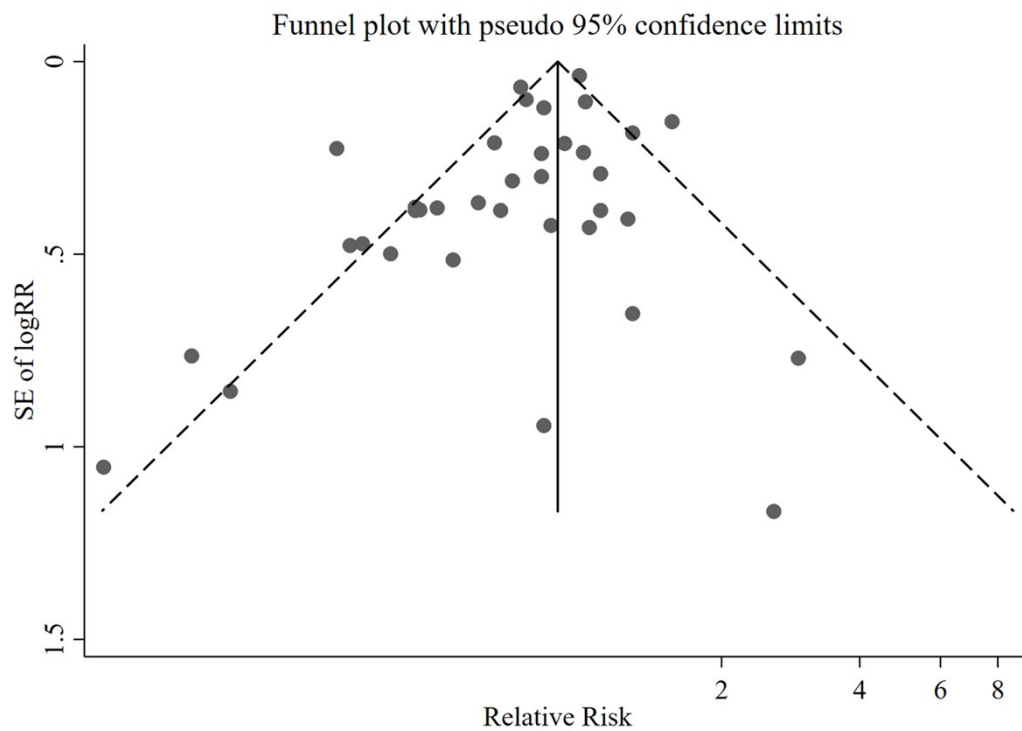
Supplementary Figure S5. Maternal 25(OH)D levels and risk of C-section, the highest versus lowest category. C-section, caesarean section.



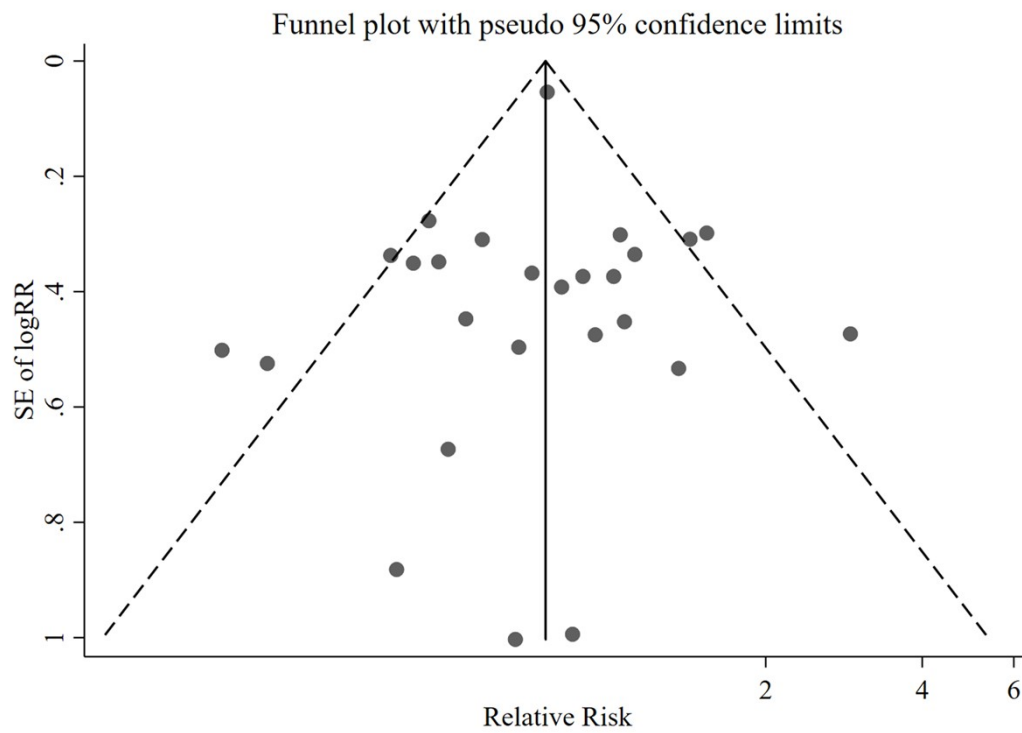
Supplementary Figure S6. Non-linear dose-response meta-analysis of maternal 25(OH)D levels and risk of C-section ($P_{\text{non-linearity}} = 0.773$). C-section, caesarean section.



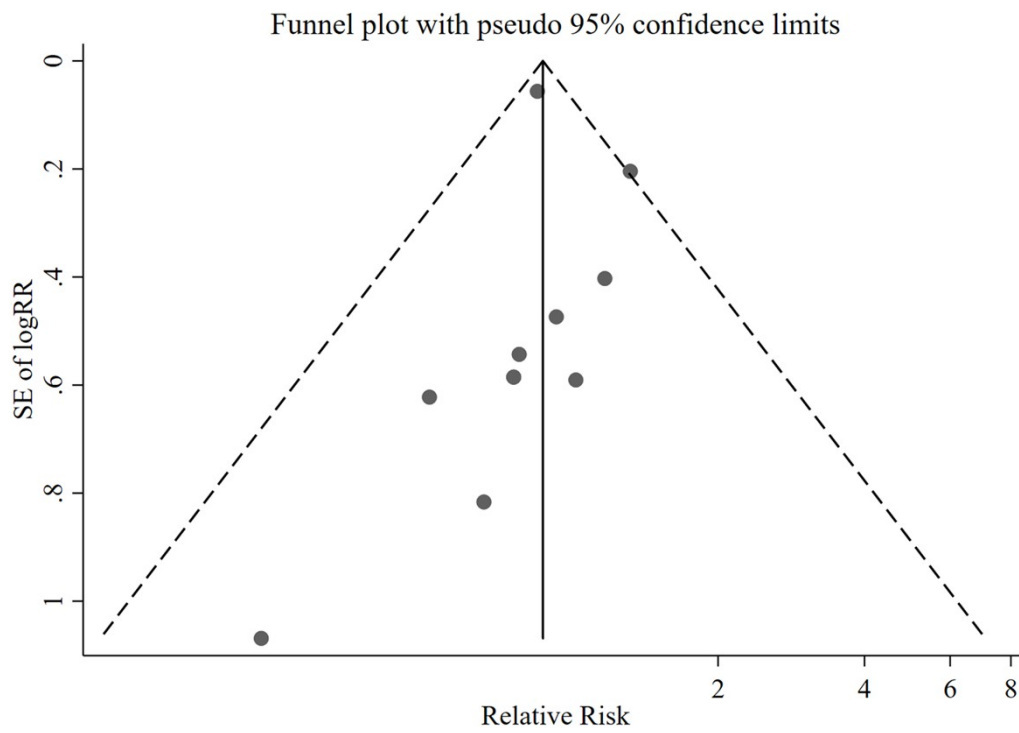
Supplementary Figure S7. Linear dose-response meta-analysis of maternal 25(OH)D levels (per 25 nmol/L increase) and risk of C-section. C-section, caesarean section.



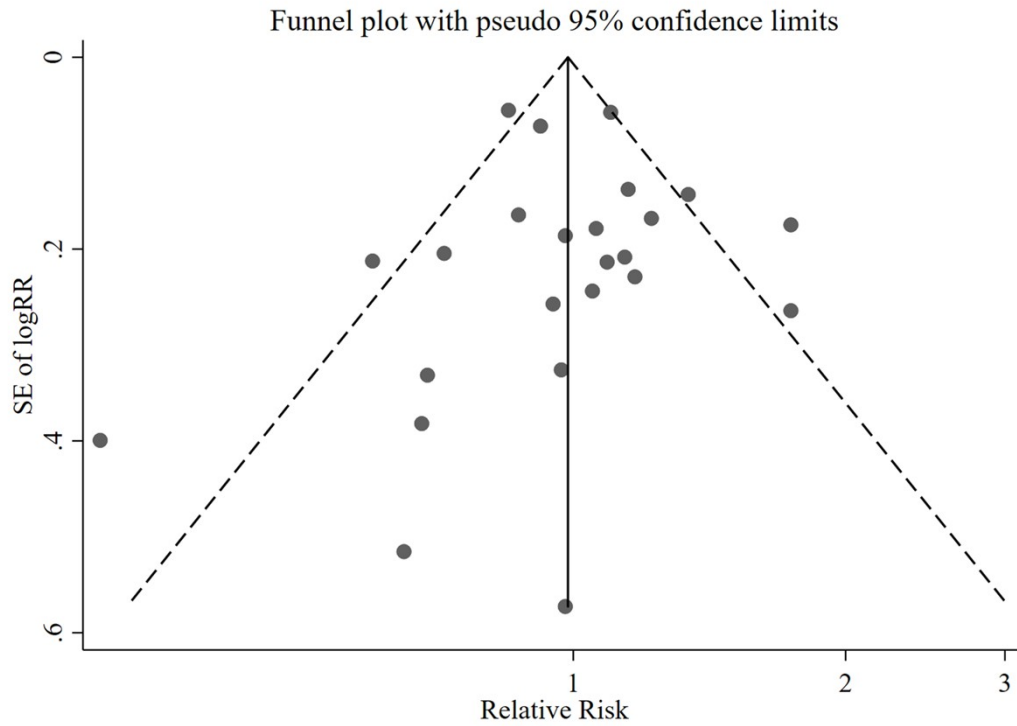
Supplementary Figure S8. Funnel plot of the risk estimates for the association between maternal 25(OH)D levels and risk of GDM, the highest versus lowest category (Egger's test $P = 0.016$). GDM, gestational diabetes mellitus.



Supplementary Figure S9. Funnel plot of the risk estimates for the association between maternal 25(OH)D levels and risk of PE, the highest versus lowest category (Egger's test $P = 0.698$). PE, pre-eclampsia.



Supplementary Figure S10. Funnel plot of the risk estimates for the association between maternal 25(OH)D levels and risk of GH, the highest versus lowest category (Egger's test $P = 0.858$). GH, gestational hypertension.



Supplementary Figure S11. Funnel plot of the risk estimates for the association between maternal 25(OH)D levels and risk of C-section, the highest versus lowest category (Egger's test $P = 0.983$). C-section, caesarean section.