

## Meta Analysis: Effect of Inadequate Gestational Weight Gain on Low Birth Weight and Small for Gestational Age

Maurizka Pitria Amrika Putranti<sup>1)</sup>, Bhisma Murti<sup>1)</sup>, Rita Benya Adriani<sup>2)</sup>

<sup>1)</sup>Master's Program in Public Health, Universitas Sebelas Maret

<sup>2)</sup>Study Program of Occupational Therapy, Health Polytechnics, Ministry of Health Surakarta

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### ABSTRACT

**Background:** Weight gain during pregnancy is related to optimizing health for both mother and baby. In addition, the increase in pregnancy weight is also an important indicator of maternal nutrition fulfillment during pregnancy and is a good measure to monitor fetal growth. This study aims to estimate the average effect of inadequate gestational weight gain on the risk of low birth weight and small for gestational age.

**Subjects and Method:** This was a systematic review and meta-analysis with PRISMA guideline and PICO model. Population: pregnant women. Intervention: inadequate gestational weight gain. Comparison: normal gestational weight gain. Outcome: low birth weight and small for gestational age. Online databases used are PubMed, SpringerLink, Scopus, and ProQuest with the keywords "Gestational Weight Gain" OR "Inadequate Weight Gain" AND "Low Birth Weight" OR "Birth Weight Infant" OR "Pregnancy Outcomes" AND "Small Gestational Age" AND "Multivariate" AND "Cohort". There were 19 cohort studies published in 2013-2022 that met the inclusion criteria. The analysis was conducted using the Review Manager 5.3 application.

**Results:** Meta-analysis using 19 cohort studies showed that pregnant women with inadequate weight gain had a risk of giving birth to infants with low birth weight 1.94 times compared to those with normal gestational weight (aOR= 1.94; CI 95%=1.74 to 2.16; p<0.001) and pregnant women with inadequate gestational weight gain had 1.69 times higher risk of giving birth to infants with small for gestational age than those with normal gestational weight (aOR= 1.69; 95% CI= 1.55 to 1.85; p<0.001).

**Conclusion:** Inadequate gestational weight gain increases the risk of low birth weight and small for gestational age.

**Keywords:** Pregnant women, gestational weight gain, low birth weight, small for gestational age

### Correspondence:

Maurizka Pitria Amrika Putranti. Master's Program in Public Health, Universitas Sebelas Maret. Jl. Ir. Sutami 36A, Surakarta 57126, Central Java, Indonesia. Email: maurizka27@gmail.com. Mobile: +6285290846373

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### BACKGROUND

Gestational weight gain (GWG) aims to optimize maternal and infant health (Siega-Riz

et al., 2019). Therefore, pregnant women need to gain weight according to the recommendations to reduce adverse health

risks. During pregnancy, mothers are not recommended to reduce weight because it will affect health outcomes. Based on the data compiled by the CDC (2022), it is known that 32% of women have a normal increase in gestational weight, 21% are inadequate, and 48% exceed recommendations.

Gestational weight gain is related to tissue growth as a natural process of pregnancy (Hector and Hebden, 2013). In addition, it is caused by the expanding uterus and uterine volume, breast enlargement and fat accumulation and new protein reserves in preparation for breastfeeding (Cunningham, 2015). Gestational weight gain is not only a nutritional indicator of pregnancy but also to monitor fetal growth and development in the womb.

Gestational weight gain that is not as recommended can result in adverse health outcomes for both the mother and fetus. The results of a study by Johnson et al. (2013) shows that excessive pregnancy weight gain increases the risk of gestational hypertension, preeclampsia, and cesarean delivery. Another study also says women with inadequate gestational weight gain can lead to babies born weighing less than normal (Goldstein et al., 2017).

Low birth weight is the newborn's birth weight of <2,500 g. An estimated 6% of babies were born with the condition in East Asia and the Pacific, 13% in Sub-Saharan Africa, and up to 28% in South Asia (WHO, 2014). Babies with low birth weight are >20 times more likely to die than neonates with a birth weight of >2,500 g (Badshah et al., 2018).

Small for gestational age are defined as weight of less than 10th percentile for gestational age and sex (WHO, 2014). Infants of this condition have high mortality compared to babies with normal birth weight and may cause perinatal death (Ota et al., 2014). In

addition, babies with this condition also tend to have learning difficulties, speech impediments as well as cognitive and behavioral disorders (Christian et al., 2014).

Newborns with these conditions will grow into unhealthy children with various growth disorders. This will have an impact on the quality of Human Resources (HR) and the burden of health costs in the future. Therefore, it is important to establish a comprehensive care strategy to reduce the risk of perinatal outcomes.

Based on the existing literature, it requires statistical summaries to calculate the estimated effect of inadequate gestational weight gain on low birth weight and small for gestational age. Meta-analyses are a statistical combination of results of two or more separate studies, with the objectives of: (1) Improving precision; (2) Answering questions not addressed by previous primary studies; and (3) Overcoming controversies arising from primary studies or generating new hypotheses (Deeks et al., 2021). This study aims to analyze previous primary studies in assessing the effect of less gestational weight gain on low birth weight and small for gestational age.

## SUBJECTS AND METHOD

### 1. Design Study

This study used systematic review method and meta-analysis using primary data from previous studies results. Articles search was conducted by using 4 databases, namely: PubMed, SpringerLink, Scopus and ProQuest. The keywords used were "Gestational Weight Gain" OR "Inadequate Weight Gain" AND "Low Birth Weight" OR "Birth Weight Infant" OR "Pregnancy Outcomes" AND "Small Gestational Age" AND "Multivariate" AND "Cohort". There were 19 primary studies of this study.

## 2. Step of Meta-analysis

- 1) Formulating research questions in PICO. The Population was healthy pregnant women. The Intervention was inadequate gestational weight gain. The Comparison was a normal gestational weight gain. The outcome was low birth weight and small for gestational age.
- 2) Searching for primary study articles from 4 online databases namely PubMed, SpringerLink, Scopus and ProQuest.
- 3) Screening and assessing the quality of primary study articles using the Critical Appraisal Skills Program for Cohort Study.
- 4) Extracting and analyzing data using RevMan 5.3 application.
- 5) Interpreting results and drawing conclusions.

## 3. Inclusion Criteria

Full paper article that used cohort design. The analysis used was multivariate with adjusted Odds Ratio (aOR). The article was published in English.

## 4. Exclusion Criteria

Non-cohort study and non-English article and the result of the analysis was in bivariate form.

## 5. Operational Definition of Variables

**Gestational weight gain**, maternal weight gain during pregnancy. It is recommended between 11.5-16 kg (IOM, 2009). Less than the recommendation (Inadequate), as recommended (Adequate), exceeding the recommendation (Excessive). Categorical scale.

**Low birth weight**, babies born weighing <2,500g. The measuring instrument was with body scales. Categorical scale.

**Small for gestational age**, babies born

with a weight of <10 percentiles for gestational age and sex. Categorical scale.

## 6. Study Instruments

The assessment of the quality of the main articles in this study uses the Critical Appraisal Checklist for Cohort Study (CASP, 2018).

## 7. Data Analysis

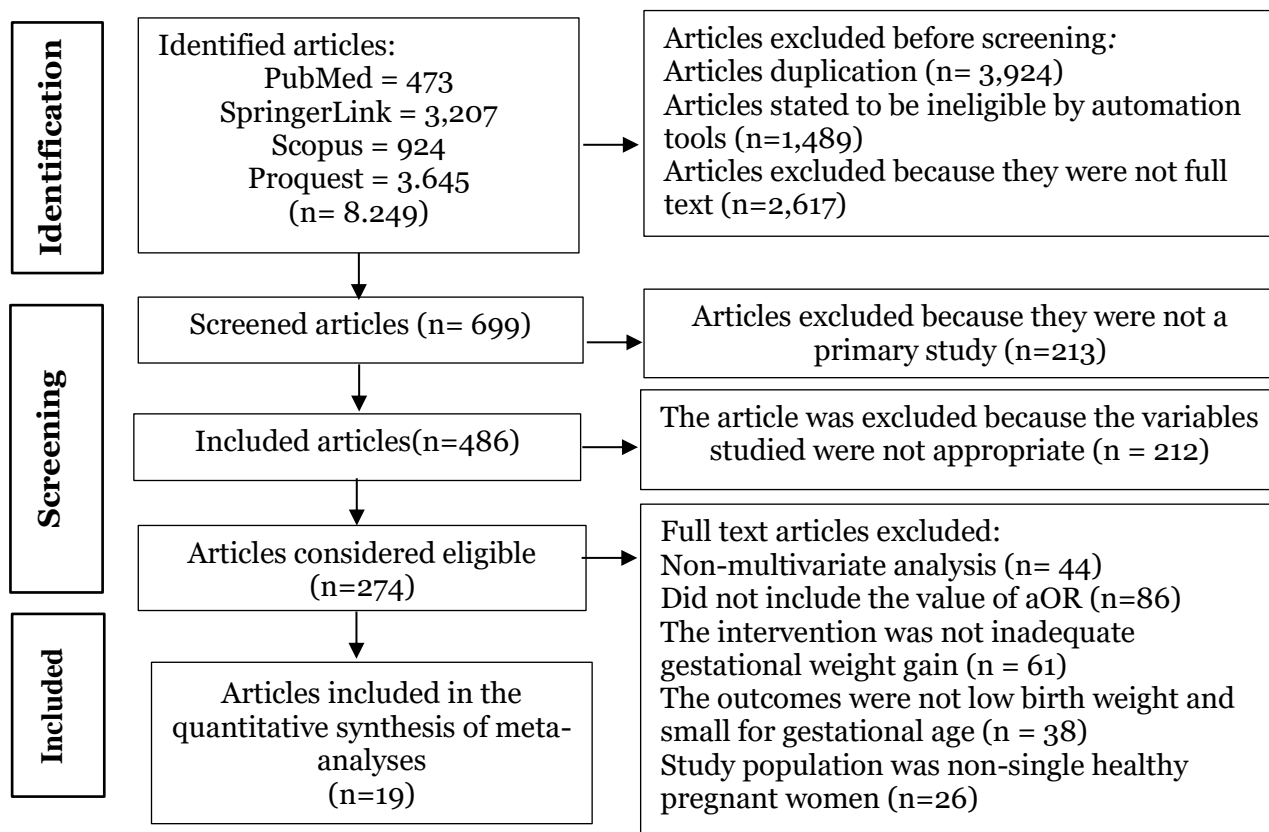
Articles in this study were collected using PRISMA diagrams. Analyzed using Review Manager 5.3 application by calculating the effect size and heterogeneity ( $I^2$ ) to form the final result of the meta-analysis. The results of the data analysis were presented in the form of forest plots and funnel plots.

## RESULTS

The process of searching for primary articles related to the effect of inadequate gestational weight gain on low birth weight and small for gestational age in this meta-analysis study was carried out on 4 online databases and obtained the results of 19 articles which can be seen in Figure 1 of the PRISMA Flow Diagram. The search for primary studies in various databases obtained 8,249 articles, after a selection process 274 articles were considered eligible for full text review, 19 articles were included in the meta-analysis synthesis.

Figure 2 shows the distribution area of the 19 primary articles used in this study, from Asia (Indonesia, Singapore, Japan, South Korea, China, Taiwan, Lebanon, and Saudi Arabia), America (United States), and Australia (New Zealand).

Table 1 shows the results of the quality assessment of the primary studies used in this study. Primary study quality assessment was conducted with the Critical Appraisal Checklist for Cohort Study (CASP, 2018).



**Figure 1. PRISMA 2020 flow diagram of the effect of inadequate gestational weight gain towards low birth weight and small for gestational age**



**Figure 2. Map of research areas of the effect of inadequate gestational weight gain towards low birth weight and small for gestational age**

Based on the results obtained from the assessment of study quality, the total score

of the 19 selected primary studies was around 24. This shows the quality of the primary articles used is feasible for the meta-analysis.

**Effects of Inadequate Gestational Weight Gain on Low Birth Weight**

Table 2 presents descriptions of 11 primary articles with cohort studies included in the meta-analysis. The studies

on the effect of inadequate gestational weight gain on low birth weight was conducted on 11,602 samples.

Table 3 presents the data of adjusted Odds Ratio (aOR) and 95% confidence interval (95% CI) of the effect of inadequate gestational weight gain on low birth weight in each primary study.

**Table 1. Quality assessment of cohort studies in meta-analyses**

Primary Studies	Question Criteria												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Aji et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Annie et al. (2019)	2	2	2	2	2	2	2	2	2	2	2	2	24
Chen et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Choi et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Chung et al. (2013)	2	2	2	2	2	2	2	2	2	2	2	2	24
Enomoto et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Fayed et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
He et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Hung et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	2	24
Hung et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Li et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	2	24
Maisa et al. (2019)	2	2	2	2	2	2	2	2	2	2	2	2	24
Rafei et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	2	24
Soltani et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Sun et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Wang et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Wu et al.(2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Zhang et al. (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Zhao et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	2	24

**Description of Question Criteria:**

- 1= Does the cohort study answer clinical problems clearly?
- 2= Was the subject of the study properly chosen?
- 3= Was exposure measured accurately to prevent bias?
- 4= Were outcomes measured accurately to minimize bias?
- 5= Did the researcher identify the important confounding factors?  
Did the researcher control confounding factors in either the design and/or data analysis phase?
- 6= Did the research subject complete the whole study time?  
Were the subjects of the study followed for a long time?
- 7= Were the results of this study reported in aOR?
- 8= How precise are the results?
- 9= Are the results reliable?
- 10= Can the results be applied to the local population?
- 11= Do the results of this study match other available evidence?
- 12= What are the implications of this study for practice?

**Descriptions of the Answer Criteria:**

- 0= No
- 1= Uncertain
- 2= Yes



**Table 2. PICO table summary of cohort articles of primary study sources with sample size (n=11,602)**

Author (Year)	Country	Sample	P	I	C	O
Aji et al. (2022)	Indonesia	104	Pregnant women of <12 weeks	Inadequate gestational weight gain	Normal gestational weight gain	LBW
Chen et al. (2020)	Taiwan	1,524	Pregnant women during the first ANC	Gestational weight gain was less than recommended	Gestational weight gain as recommended	LBW
Choi et al. (2022)	South Korea	1,242	Gestational age of <8 weeks	Less standard gestational weight	Standard gestational weight	LBW
Fayed et al. (2022)	Saudi Arabia	2,972	Pregnancy <10 weeks	Inappropriate gestational weight gain	Proper gestational weight gain	LBW
Hung et al. (2015)	Taiwan	2,574	Mothers with fetal age of 10 weeks	Inadequate pregnancy weight	Adequate gestational weight	LBW
Hung et al. (2016)	Taiwan	3,146	Pregnancy <12 weeks	Inadequate gestational weight gain	Adequate weight gain during pregnancy	LBW
Soltani et al. (2017)	Indonesia	268	Pregnant mothers on the first ANC visit	Inadequate gestational weight gain	Normal gestational weight gain	LBW
Sun et al. (2020)	China	787	Gestational age of 8 weeks	Pregnancy weight gain was not achieved	Gestational weight gain achieved	LBW
Wu et al. (2022)	China	750	Mothers with Gestational age of <8 weeks	Inadequate gestational weight	Adequate gestational weight	LBW
Zhang et al. (2021)	China	821	Women with single pregnancy and healthy	Gestational weight was less than standard	Standard gestational weight	LBW
Zhao et al. (2018)	China	246	Healthy Pregnant Women	The weight of pregnant woman was less than the recommendation	Weight of pregnant women according to recommendations	LBW

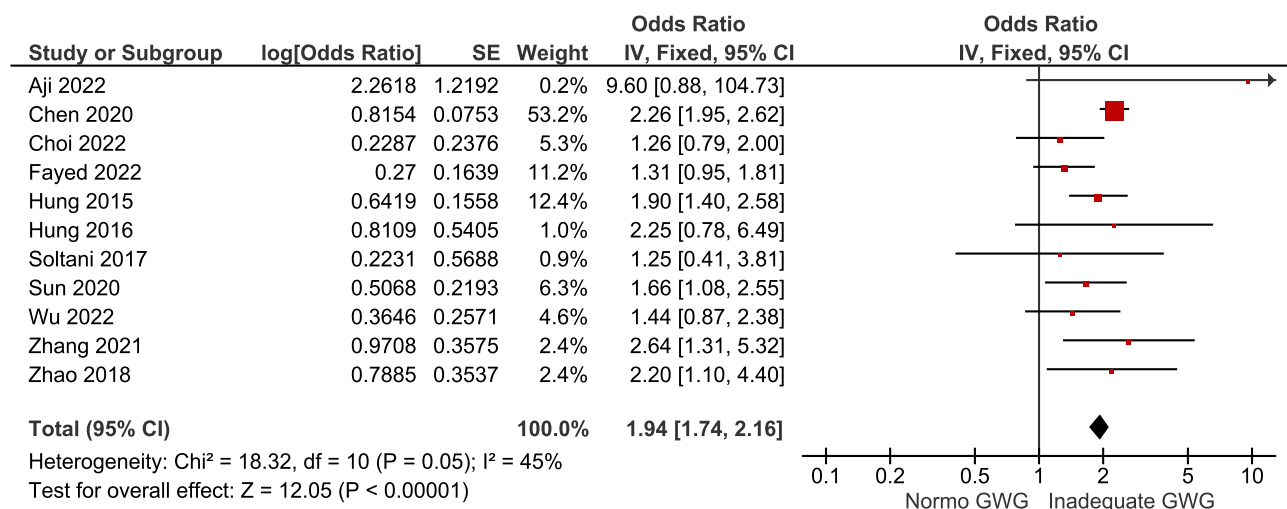
**Table 3. Data of adjusted Odds Ratio (aOR) and CI 95% of the effect of inadequate gestational weight gain on low birth weight**

Author (Year)	aOR	CI 95%	
		Upper Limit	Lower Limit
Aji et al. (2022)	9.6	0.88	105.2
Chen et al. (2020)	2.26	1.95	2.62
Choi et al. (2021)	1.257	0.789	2.003
Fayed et al. (2022)	1.31	0.95	1.81
Hung et al. (2015)	1.9	1.4	2.4
Hung et al. (2016)	2.25	0.78	6.44
Soltani et al. (2017)	1.25	0.41	3.86
Sun et al. (2020)	1.66	1.08	2.56
Wu et al. (2022)	1.44	0.87	2.39
Zhang et al. (2021)	2.64	1.31	5.33
Zhao et al. (2018)	2.2	1.1	4.4

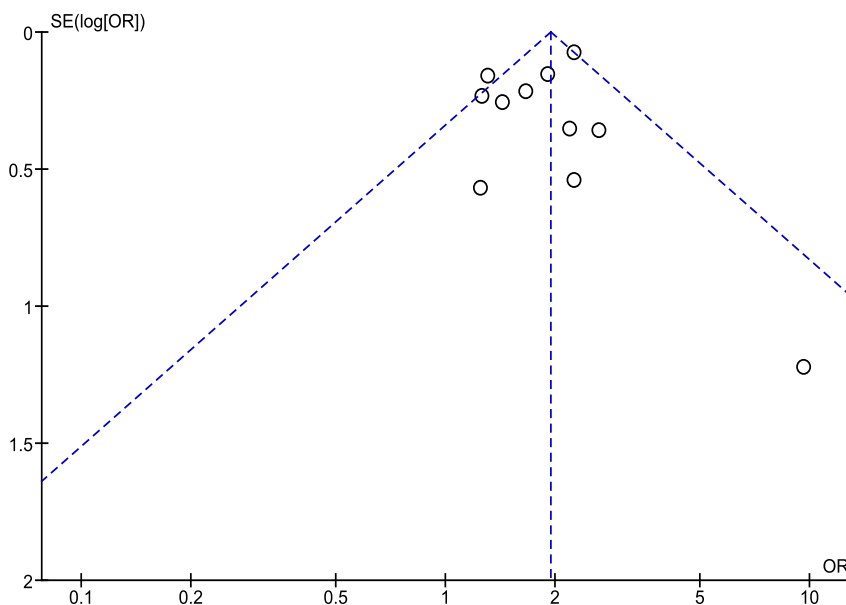
Forest plots in Figure 3 show that an inadequate gestational weight gain increased the risk of low birth weight by 1.94 times compared to a normal gestational weight gain. The results were statistically significant (aOR= 1.94; CI 95%= 1.74 to 2.16;  $p < 0.001$ ). Forest plots also show heterogeneity of low effect estimates across primary studies ( $I^2 = 45\%$ ;  $p = 0.050$ ). So that the calculation of the effect estimates was carried

out with a fixed effect model approach.

The funnel plots in Figure 4 shows the asymmetric distribution of effect estimates across studies, i.e. the distribution of effects to the right of the vertical line of the average effect estimate is relatively greater than that of the left (overestimate). Thus, the funnel plot indicates that there was a publication bias.



**Figure 3. Forest plots of the effect of inadequate gestational weight gain on low birth weight**



**Figure 4. Funnel plot of the effect of inadequate gestational weight gain on low birth weight**

### The Effect of Inadequate Gestational Weight Gain on Small for Gestational Age

Table 4 presents descriptions of 15 primary articles with cohort studies included in the meta-analysis. Studies on the effect of inadequate gestational weight gain on small for gestational age was conducted on 53,752 samples.

Table 5 presents the data of adjusted odds ratio (aOR) and 95% confidence interval (95%) data of the effect of inadequate

gestational weight gain on small for gestational age in each primary study.

The forest plots in Figure 5 show inadequate gestational weight gain increased the risk of small for gestational age by 1.69 times compared to normal gestational weight gain and the results were statistically significant (aOR= 1.69; CI 95%= 1.55 to 1.85;  $p < 0.001$ ). Forest plots show high heterogeneity across primary studies ( $I^2 = 54\%$ ;  $p = 0.007$ ). The calculation of effect estimates was conducted using a random effect model.

**Table 4. PICO table summary of cohort articles of primary study sources with sample size (n=53,752)**

Author (Year)	Country	Sample	P	I	C	O
Annie et al. (2019)	United States	1,666	Pregnant women of <12 weeks	Inadequate gestational weight gain	Normal gestational weight gain	Small for gestational age
Chung et al. (2013)	New Zealand	167	Gestational age <8 weeks	Gestational weight less than standard	Standard pregnancy weight	Small for gestational age
Enomoto et al. (2016)	Japan	2,032	Pregnancy of <10 weeks	Inappropriate Gestational weight gain	Proper gestational weight gain	Small for gestational age
He et al. (2022)	Singapore	240	Pregnant women during 1 <sup>st</sup> ANC	Gestational weight gain less than recommended	Gestational weight gain as recommended	Small for gestational age
Hung et al. (2015)	Taiwan	2,574	Mothers with fetal age of 10 weeks	Inadequate gestational weight	Adequate gestational weight	Small for gestational age
Hung et al. (2016)	Taiwan	3,146	Gestational age 12 weeks	Weight gain during pregnancy was failing to achieve	Weight gain during pregnancy was achieved	Small for gestational age
Li et al. (2013)	United States	3,340	Mother with gestational age <8 weeks	Inadequate gestational weight	Adequate gestational weight	Small for gestational age
Maisa et al. (2019)	United States	1,428	Pregnant Women	Gestational weight was less than the recommendation	Gestational weight was in accordance with the recommendations	Small for gestational age
Rafei et al. (2015)	Lebanon	35,902	Women with healthy single pregnancy	Gestational weight was less than standard	Gestational weight was in accordance with the standard	Small for gestational age



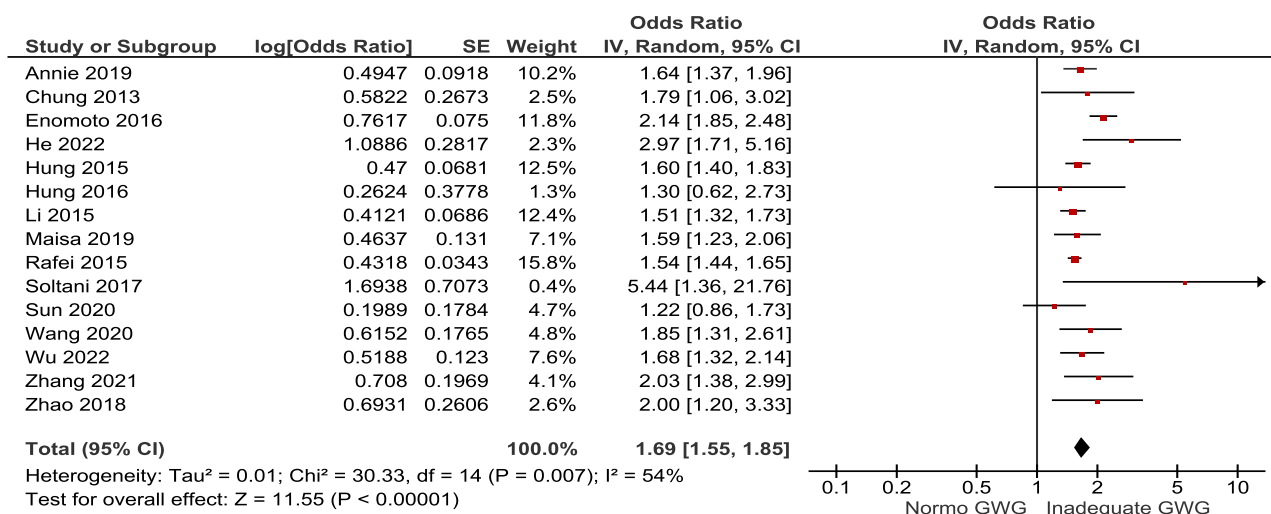
Author (Year)	Country	Sample	P	I	C	O
Soltani et al. (2017)	Indonesia	268	Pregnant women in the first ANC visit	Inadequate gestational weight gain	Normal gestational weight gain	Small for gestational age
Sun et al. (2020)	China	787	Gestational age of 8 weeks	Gestational weight gain was not achieved	Gestational weight gain was achieved	Small for gestational age
Wang et al. (2020)	China	885	Pregnancy age of <10 weeks	Inappropriate gestational weight gain	Appropriate gestational weight gain	Small for gestational age
Wu et al. (2022)	China	750	Pregnant age of <8 weeks	Inadequate gestational weight	Adequate gestational weight	Small for gestational age
Zhang et al. (2021)	China	821	Women with healthy single pregnancy	Gestational weight was less than standard	Gestational weight was in accordance with the standard	Small for gestational age
Zhao et al. (2018)	China	246	Pregnant women with gestational age of <10 weeks	Inadequate gestational weight gain	Normal gestational weight gain	Small for gestational age

The funnels in Figure 6 show the asymmetric distribution of effect estimates across studies, i.e. the distribution of effects on the right of the vertical line of the average

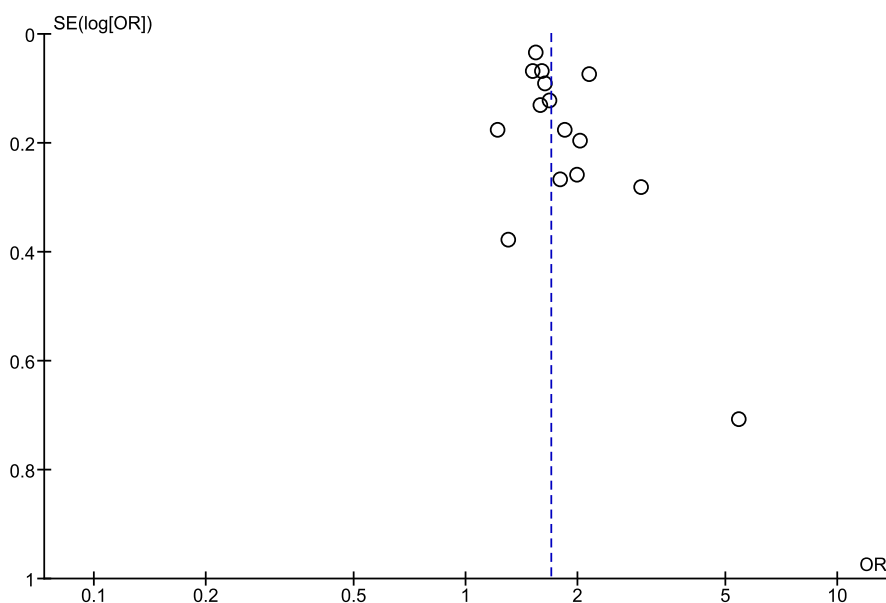
effect estimates are greater than on the left (overestimate). Thus, the funnel plots indicate that there was a publication bias.

**Table 5. Data of adjusted odds ratio (aOR) and 95% CI of the effect of inadequate gestational weight gain on small for gestational age**

Author (Year)	aOR	95% CI	
		Upper Limit	Lower Limit
Annie et al. (2019)	1.64	1.37	1.96
Chung et al. (2013)	1.79	1.06	3.00
Enomoto et al. (2016)	2.142	1.849	2482
He et al. (2022)	2.97	1.71	5.15
Hung et al. (2015)	1.6	1.4	1.9
Hung et al. (2016)	1.30	0.62	2.72
Li et al. (2013)	1.51	1.32	1.72
Maisa et al. (2019)	1.59	1.23	2.06
Rafei et al. (2015)	1.54	1.44	1.64
Soltani et al. (2017)	5.44	1.36	21.77
Sun et al. (2020)	1.22	0.86	1.75
Wang et al. (2020)	1.850	1.309	2.616
Wu et al. (2022)	1.68	1.32	2.13
Zhang et al. (2021)	2.0	1.38	2.96
Zhao et al. (2018)	2.0	1.2	3.4



**Figure 5. Forest plots of the effect of inadequate gestational weight gain on small for gestational age**



**Figure 6. Funnel plots of the effect of inadequate gestational weight gain on small for gestational age**

**DISCUSSION**

**1. The Effects of Inadequate Gestational Weight Gain on Low Birth Weight**

This meta-analysis study provided evidence that inadequate gestational weight gain increases the risk of low birth weight.

These results are in line with a study by Sun et al. (2020) which shows that inadequate gestational weight gain increases the risk

of low birth weight (aOR= 1.66; CI 95%= 1.08 to 2.26; p=0.002). Another study by Fayed et al., (2022) also shows similar results that inadequate gestational weight gain is associated with the incidence of low birth weight by 1.31 times compared to adequate weight gain (aOR= 1.31; CI 95%= 0.95 to 1.81; p<0.001).

Based on the above studies, it is acknowledged that gestational weight gain that

is less than the recommendation can increase the risk of giving birth to babies with low birth weight. It is explained by Tela et al. (2019) which states that gestational weight gain has a significant effect on birth weight. An increase in gestational weight of 1 kg is associated with a baby weight gain of 97 g. According to Muthayya et al. (2019) it is because weight gain during pregnancy is an important indicator of nutrition in pregnancy and contributes significantly to fetal growth in the womb. Therefore, it is important for women to achieve gestational weight gain. It is due to adequate gestational weight gain as an effort to prevent the incidence of babies born with low-birth-weight.

## **2. The Effect of Inadequate Gestational Weight Gain on Small for Gestational Age**

Meta-analysis study discovered the effect of inadequate gestational weight gain on small gestational infants was 1.62 times compared to normal gestational weight gain, and the results were statistically significant.

The results of this study are in line with a study by He et al. (2022) which showed that the gestational weight gain that is less than the recommendation can increase the risk of small for gestational age babies by 2.97 times compared to an adequate weight gain (aOR= 2.97; CI 95%= 1.71 to 5.15;  $p < 0.001$ ). Another study by Wang et al., (2020) also states that inadequate gestational weight gain increases the risk of a small for gestational age by 1,850 times compared to normal gestational weight gain (aOR= 1,850; CI 95%= 1.309 to 2.616;  $p < 0.001$ ).

Based on some of these studies, it is acknowledged that inadequate gestational weight gain can increase the risk of giving birth to small for gestational age babies. This condition is related to the fetus that responds to a reduction in nutrient supply by reducing its overall size but maintaining certain functions such as brain growth, lung

maturation, and increased red blood cell production. This is an effort to optimize survival chances (Tudehope et al., 2013). According to a study by Landau et al., (2019) the fetus prioritizes blood supply to more vital organs such as the brain, heart, and placenta. Therefore, fetus can experience a decrease in total body fat which results in the baby looking thinner compared to other babies of the same gestational age. Therefore, weight gain during pregnancy is very important for mothers to achieve because adequate gestational weight gain is an effort to prevent the incidence of small for gestational age babies.

## **AUTHOR CONTRIBUTION**

Maurizka Pitria Amrika Putranti as the main researcher is in charge of selecting research topics, searching and evaluating articles, as well as data analysis. Bhisma Murti and Rita Benya Adriani acted as supervisors.

## **FUNDING AND SPONSORSHIP**

The study was self-funded.

## **CONFLICT OF INTERESTS**

There is no conflict of interest.

## **ACKNOWLEDGMENT**

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