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Meta-analysis

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Meta-Analysis of the Effects of Sleep Duration, Exercise, and Family Income on Obesity in Children

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ABSTRACT

Background: Obesity is still one of the problems in Indonesia. The obesity problem has grown into an epidemic, with more than 4 million people dying each year. Factors causing obesity such as lifestyle, lack of physical activity, poor diet habits, low family income, sleep duration, and others. This study aims to estimate the effect of sleep duration, exercise, and family income on obesity in children.
Subjects and Method: A systematic review and meta-analysis were conducted using PRISMA guidelines and the PICO model. Population= children of 2-18 years. Intervention= short sleep duration, exercise, and high family income. Comparison= long sleep duration, no exercise, and low family income. Outcome= Obesity. Articles were collected from databases such as Google Scholar, PubMed, Science Direct, and ResearchGate. The literature search used the keywords "family income" AND "exercise" AND "sleep duration" AND "obesity" AND "children" AND "cross-sectional". A total of 19 articles met the inclusion criteria for the meta-analysis, and subsequently were assessed using RevMan 5.4.
Results: A meta-analysis of studies from Japan, Korea, Ethiopia, China, Morocco, Saudi Arabia, and Ghana showed that children with short sleep duration (aOR= 1.83; CI 95%= 1.22 to 2.73; p= 0.003), children with high family income (aOR= 1.18; CI 95%= 1.03 to 1.36; p= 0.020) could increase the incidence of obesity, and those results were statistically significant. Exercise can reduce the incidence of obesity in children, but this risk of reduction was not statistically significant (aOR= 0.80; CI 95%= 0.59 to 1.09; p= 0.150).
Conclusion: Short sleep duration and high family income increase the incidence of obesity in children, and these results are statistically significant. Exercise decreases the incidence of obesity in children, but the risk of decline is not statistically significant.

Keywords: family income, exercise, sleep duration, obesity, children

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BACKGROUND

Obesity is defined as the accumulation of abnormal or excessive fat that inflicts a health risk. A Body Mass Index (BMI) over 30 is considered obese. The problem has developed into an epidemic, with more than 4 million people dying each year from being overweight or obese in 2017 according to the

global burden of disease. Rates of overweight and obesity continue to rise in adults and children. From 1975 to 2016, the prevalence of overweight or obese children and adolescents aged 5–19 is more than quadrupled from 4% to 18% globally (WHO, 2021).

Globally, the prevalence of obesity has nearly tripled since the 1970s. For example, about 1.9 billion adults (18+ years) were overweight in 2016, of whom 650 million were obese. In the same year, 41 million children under the age of five were overweight or obese. Over 340 million children and adolescents aged 5–19 were overweight or obese in 2016 (WHO, 2018). Obesity refers to the abnormal or excessive accumulation of fat due to an energy imbalance between calories consumed and calories expended. Some factors of obesity such as a sedentary lifestyle, lack of physical activity, and poor diet habits, include the consumption of savory foods with hidden fats and sugars that interfere with metabolism. Other factors include bio-physiological causes such as genetic, insulin resistance, hyperinsulinism, and disruption of normal satiety feedback mechanisms (WHO, 2018).

In children's growth and development, sleep quality is also one of the supporting factors for their health. Decreased sleep duration can increase the risk of obesity (Malik et al., 2020). In addition, the lack of physical activity in children today is also a factor in the occurrence of obesity. A study in China shows that the prevalence of children aged 9-11 years are more likely to have higher body weight and less physical activity (Liu et al., 2021).

Furthermore, child obesity also closely related to the income or earnings of a family. Many studies have been conducted in developed countries that low social economic status increases the risk factors for childhood obesity. Socioeconomically, obesity has an association with the amount of income earned by a family. Children of parents with above-average monthly income are nearly 17 times more likely to be overweight compared to those of a family with a below-average monthly income (Desalew et al., 2017).

Based on these data, it requires a more thorough study of the results of the various previous studies. Various studies' results are combined in a meta-analysis study design to measure the effect size so that a quantitative summary of results is obtained (Murti, 2018). This study aims to estimate the effect of sleep duration, exercise, and family income on obesity in children.

SUBJECTS AND METHOD

1. Study Design

The study used systematic review and meta-analysis method, it is a method to analyze data derived from primary studies from databases based on PRISMA diagrams. The article search in this study used electronic databases such as Google Scholar, PubMed, Science Direct, and Research Gate. The articles used were published from 2013-2022. The keywords used to search for articles were “family income" AND exercise AND "sleep duration" AND obesity AND children AND "cross-sectional".

2. Steps of Meta-Analysis

The meta-analysis was carried out through 5 steps as follows:

1) Formulating research questions using the PICO model includes P= children aged 2-18 years; I= short sleep duration, exercise, and high family income; C= long sleep duration, no exercise, and low family income.
2) Searching for primary study articles from electronic databases
3) Conducting screening and critical appraisal of primary studies.
4) Performing data extraction and inputting effect estimates from each primary study

into the RevMan 5.3. The results of the article analysis were presented in aOR, with 95% confidence interval (CI) using model effects and data heterogeneity (I^2).

5) Interpreting results and drawing conclusions.

3. Inclusion Criteria

The inclusion criteria in this study were cross-sectional study full text articles, multivariate analysis with adjusted odds ratio (aOR) to measure the effect estimates, the study subject was children, and the outcome was obesity.

4. Exclusion Criteria

Study articles were published before 2013, and study articles were published in a non-English language.

5. Operational Definition of Variables

Obesity: is a medical condition in the form of above-normal body weight due to excess fat accumulation and Body Mass Index (BMI) higher than normal (BMI ≥27kg/ m^2).

Sleep duration: is the duration of sleep divided into four levels according to the National Sleep Foundation (NSF) guidelines. Sleep duration <7 hours/day is classified as very short, within 7 to 8 hours/ day as short, within 9 to 11 hours/day as recommended, and >11 hours/day as long.

Family income: is the sum of all fixed and side income of a husband and wife in each month divided by the total number of dependent family members. Monthly family income is categorized as low when it is less than 586.43 US$ and is categorized as high if monthly income is more than 977.38 US$.

Exercise: is one's physical and psychological activity that is useful for maintaining and improving the quality of one's health which is done regularly 2-3 times per week.

6. Study Instruments

This study used PRISMA flowchart guidelines and the quality assessment used in this study was the 2018 Critical Appraisal Skills Program (CASP).

7. Data Analysis

The data processing used was RevMan 5.3 by calculating effect size and heterogeneity to determine the combined study model and form the final results of the meta-analysis.

RESULTS

An initial search of 4 databases yielded 959 articles, then removal was made for 354 articles duplications. The next process was the screening of full-text articles that met the criteria resulting in 77 articles, and the final result of articles synthesis selected for the meta-analysis was 19 articles.

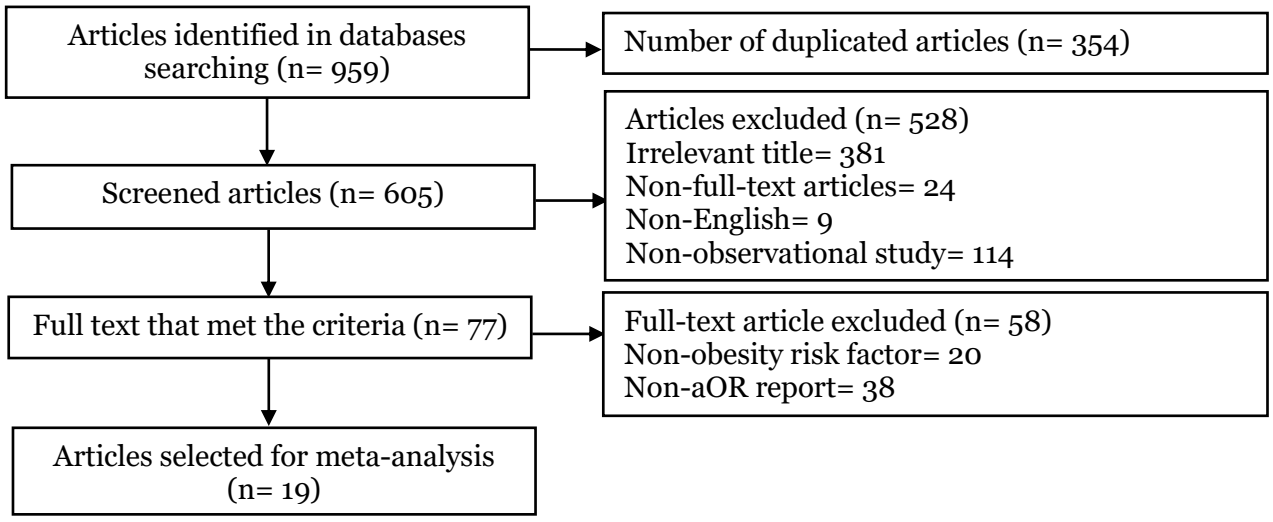

Figure1. PRISMA Flow Diagram

Figure 2 shows an overview of the study areas used in this meta-analysis that spread across 2 continents, Africa and Asia. A total of 19 articles at the end of the review process met quantitative needs. All articles used cross sectional studies.

Figure 2. The cross-sectional study area of the effect of sleep duration, exercise, and family income on obesity in children

Table 1. Critical appraisal checklist for cohort studies in meta-analysis

Primary Study	Criteria of Questions												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Zhang et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Kabbaoui et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	2	24
Dereje et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	1	23
Jallow-Badjad et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Fan et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Wang et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Chen et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24
Zhang et al. (2016)	2	2	2	2	2	2	2	2	2	2	2	2	24
Kabbaoui et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	2	24
Beyen et al. (2013)	2	2	2	2	2	2	2	2	2	2	2	2	24
Aryeetey et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Desalew et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Ganle et al. (2019)	2	2	2	2	2	2	2	2	1	2	2	2	23
Liu et al. (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Kachi et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	1	23
Su et al. (2015)	2	2	2	2	2	2	2	2	2	2	2	1	23
Lee et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Chen et al. (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Al-Hazza et al. (2022)	2	2	2	2	2	2	2	2	2	2	2	2	24

Description of the question criteria:

1 = Did the study address a clearly focused question / issue?
2 = Is the research method (study design) appropriate for answering the research question?
3 = Is the method of selection of the subjects (employees, teams, divisions, organizations) clearly described?
4 = Could the way the sample was obtained introduce (selection)bias?
5 = Was the sample of subjects representative with regard to the population to which the findings will be referred?
6 = Was the sample size based on pre-study considerations of statistical power?
7 = Was a satisfactory response rate achieved?
8 = Are the measurements (questionnaires) likely to be valid and reliable?
9 = Was the statistical significance assessed?
10 = Are confidence intervals given for the main results?
11 = Could there be confounding factors that haven't been accounted for?
12 = Can the results be applied to your organization?

Description of the answer score:

0 = No
1 = Can't tell
2 = Yess

Table 2. Description of cross-sectional studies of the effect of sleep duration on obesity in children

Author (year)	Country	Sample size	P	I	C	O
Zhang et al. (2016)	Guangzhou	4,942	Children aged 7-12 years	Short sleep duration	Long sleep duration	Obesity
Kabbaoui et al. (2018)	Morocco	1,818	Children aged 12-18 years	Short sleep duration, high family income	Long sleep duration, low family income	Obesity
Dereje et al. (2018)	Ethiopia	127,056	Children aged 13-18 years	Short sleep duration, exercise	Long sleep duration, no exercise	Obesity
Jallow-Badjad et al. (2020)	Gambia	805	Children aged 13-18 years	Short sleep duration	Long sleep duration	Obesity
Fan et al. (2020)	China	35,414	Children aged 6-17 years	Short sleep duration, exercise, high family income	Long sleep duration, no exercise, Low family income	Obesity
Wang et al. (2022)	Henan	18,723	Children aged 6-17 years	Short sleep duration	Long sleep duration	Obesity
Chen et al. (2022)	China	2,254	Children aged 8-16 years	Short sleep duration	Long sleep duration	Obesity
Zhang et al. (2016)	Guangzhou	4,942	Children aged 7-12 years	Short sleep duration	Long sleep duration	Obesity
Kabbaoui et al. (2018)	Morocco	1,818	Children aged 12-18 years	Short sleep duration, high family income	Long sleep duration	Obesity
Beyen et al. (2013)	Ethiopia	800	Children aged 14-18 years	Exercise	No exercise	Obesity
Aryeetey et al. (2017)	Ghana	3,089	Children aged 9–15 years	Exercise	No exercise	Obesity

Author (year)	Country	Sample size	P	I	C	O
Desalew et al. (2017)	Ethiopia	38,376	Children aged 5-8 years	Exercise	No exercise	Obesity
Ganle et al. (2019)	Ghana	285	Children aged 5-16 years	Exercise	No exercise	Obesity
Liu et al. (2021)	Beijing	10,855	Children aged 6-18 years	Exercise	No exercise	Obesity
Kachi et al. (2015)	Japan	397	Children aged 6-11 years	High family income	Low family income	Obesity
Su et al. (2015)	China	3,391	Children aged 7-17 years	High family income	Low family income	Obesity
Lee et al. (2020)	Korea	14,482	Children aged 2-18 years	High family income	Low family income	Obesity
Chen et al. (2021)	China	17,007	Children aged 6-12 years	High family income	Low family income	Obesity
Al-Hazza et al. (2022)	Saudi Arabia	2,169	Children aged 6-13 years	High family income	Low family income	Obesity

Table 3. Adjusted Odd Ratio (aOR) of the effect of short sleep duration on obesity in children

Author (Year)	aOR	95%CI	
		Lower Limit	Upper Limit
Zhang et al. (2016)	0.93	0.47	1.85
Kabbaoui et al. (2018)	1.03	0.73	1.454
Dereje et al. (2018)	3.69	1.94	7.04
Jallow-Badjad et al. (2020)	2.53	1.07	5.99
Fan et al. (2020)	3.01	2.19	4.15
Wang et al. (2022)	2.26	1.21	2.83
Chen et al. (2022)	1.32	1.06	1.64
Zhang et al. (2016)	0.93	0.47	1.85
Kabbaoui et al. (2018)	1.03	0.73	1.454

The forest plot in Figure 3 shows that short sleep duration had an effect on obesity in children. Children with short sleep duration were 1.83 times more likely to have a risk of obesity compared to children with long sleep duration, and this result was statistically significant (aOR= 1.83; CI 95%= 1.22 to 2.73; p= 0.003). The forest plot also shows high heterogeneity of effect estimates across primary studies I^2= 83%; p<0.001. Thus, the calculation of the average effect estimates was conducted using a random effect model approach.

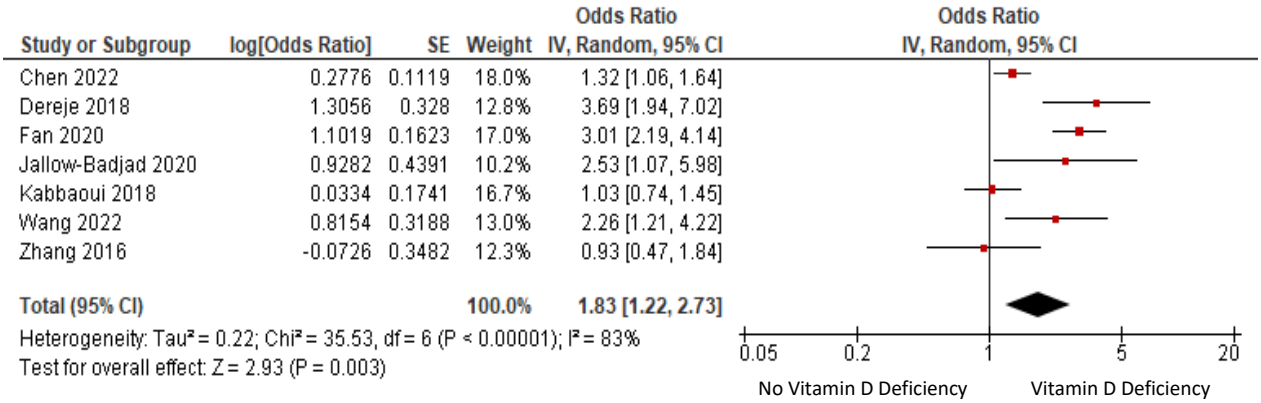

Figure 3. Forest plot of the effect of short sleep duration on obesity in children

The funnel plot in Figure 4 shows a fairly balanced distribution of effect estimates to the right and left of the vertical line of the average effect estimates. Thus, the funnel plot does not indicate any publication bias.

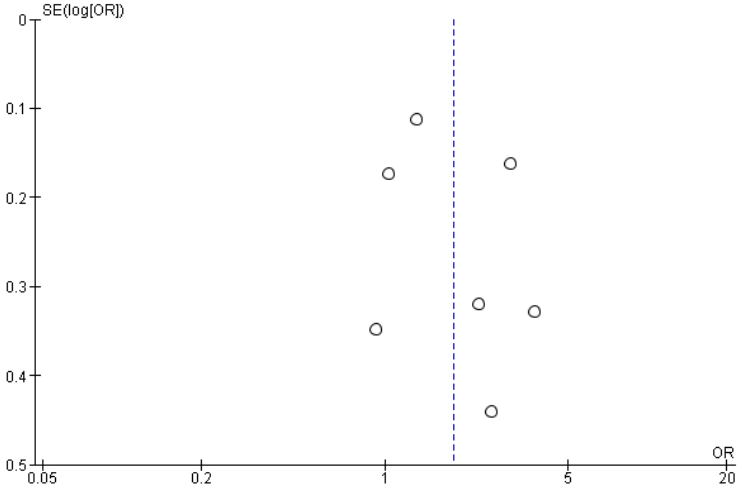

Figure 4. Funnel plot of the effect of short sleep duration on obesity in children

Table 5. Adjusted Odd Ratio (aOR) of the effect of exercise on obesity in children

Author (Year)	aOR	95 % CI	
		Lower limit	Upper limit
Beyen et al. (2013)	1.99	0.95	4.16
Aryeetey et al. (2017)	0.69	0.52	0.93
Desalew et al. (2017)	0.26	0.10	0.67
Dereje et al. (2018)	0.38	0.14	0.97
Ganle et al. (2019)	0.56	0.33	0.96
Fan et al. (2020)	1.27	1.17	1.38
Liu et al. (2021)	0.85	0.77	0.94

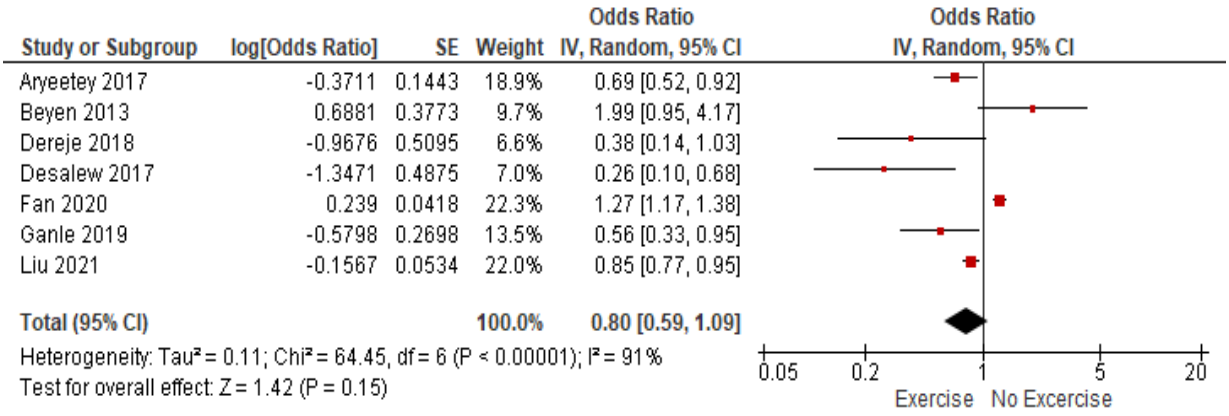

Figure 5. Forest plot of the effect of exercise on obesity in children

The forest plot in Figure 5 shows that exercise had an effect on obesity in children. Children who exercised were 0.80 times more likely to have a risk of obesity compared to children with no exercise, however the risk reduction was not statistically significant (aOR= 0.80; CI 95%= 0.59 to 1.09; p= 0.150). The figure also shows high

heterogeneity of effect estimates across primary studies I^2= 91%; p<0.001. The calculation of average effect estimates use a random effect model.

The funnel plot in Figure 6 shows that the distributions of effect estimate of the primary meta-analysis studies were more to the left of the vertical line of the average estimates than to the right, indicating publication bias. Since the publication bias was more likely to the left of the average vertical line which was in the same direction as the position of the diamond shape in the forest plot, the publication bias was more likely to add to the actual effect of exercise on obesity in children (over-estimate)

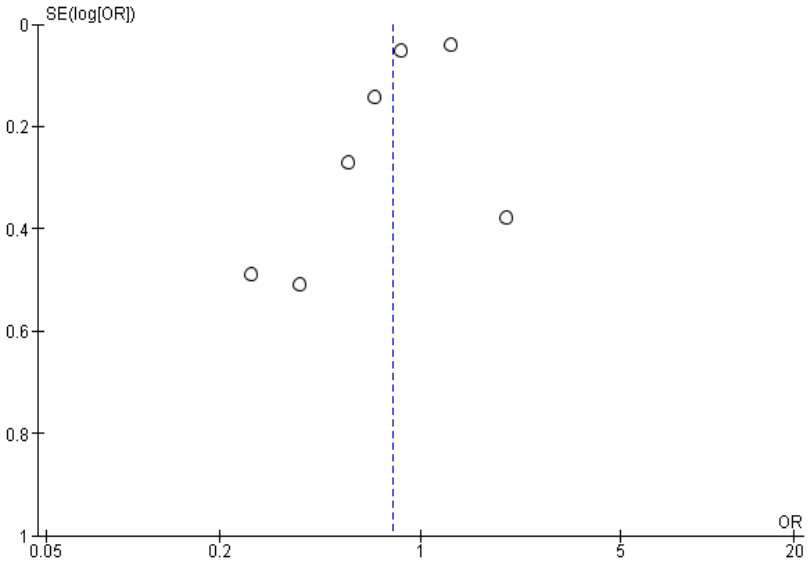

Figure 6. Funnel plot of the effect of exercise on obesity in children

Table 6. Adjusted Odd Ratio (aOR) of the effect of family income on obesity in children

Author (Year)	aOR	95 % CI	
		Lower limit	Upper limit
Kachi et al. (2015)	0.67	0.11	4.17
Su et al. (2015)	1.11	0.81	1.53
Kabbaoui et al. (2018)	2.11	1.081	4.138
Lee et al. (2020)	0.73	0.37	1.47)
Fan et al. (2020)	1.29	1.06	1.58)
Chen et al. (2021)	1.11	0.745	1.661)
Al-Hazza et al. (2022)	0.95	0.634	1.451

The forest plot in Figure 7 shows that high family income had an effect on childhood obesity. Children with high family income were 1.18 times more likely to have the risk of obesity compared to children with low family income, and this result was statistically significant (aOR= 1.18; CI 95%= 1.03 to 1.36; p = 0.020). The forest plot also shows high heterogeneity of effect estimates across primary studies I^2= 16%; p<0.001. Thus, the calculation of the average effect estimates was conducted by using a fixed effect model approach.

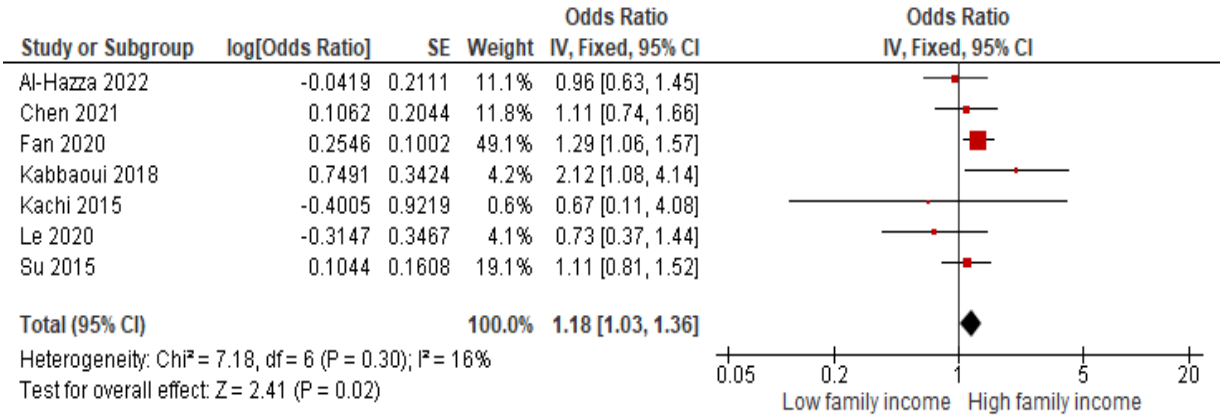

Figure 7. Forest plot of the effect of family income on obesity in children

The funnel plot in Figure 8 shows that the distributions of the effect estimate of the primary studies meta-analysis were more to the left of the vertical line of average estimates than to the right, indicating publication bias. Because the publication bias was more likely to the left of the average vertical line which was different from the position of the diamond shape in the forest plot, the publication bias was more likely to add to the actual effect of high family income on childhood obesity (underestimate).

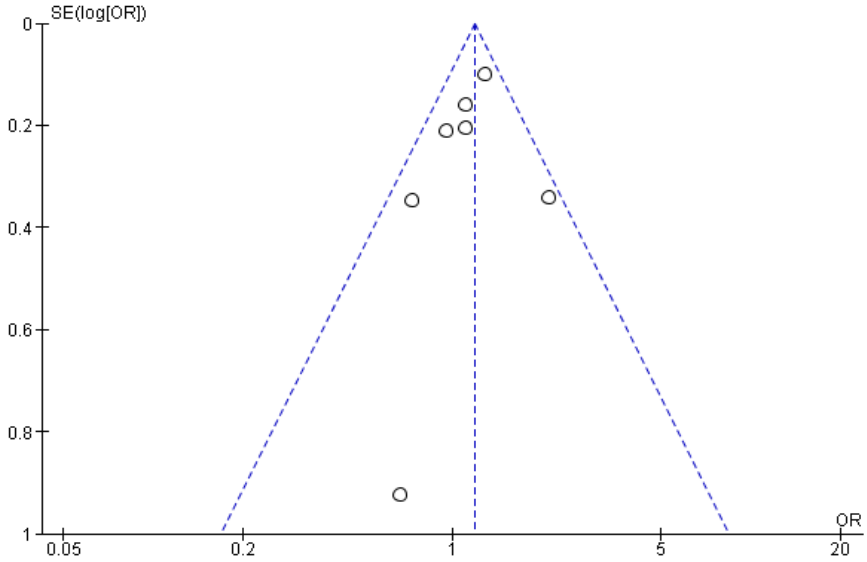

Figure 8. Funnel plot of the effect of family income on Obesity in Children

DISCUSSION

1. The effect of sleep duration on obesity in children.

Sleep duration is divided into four levels according to the National Sleep Foundation (NSF) guidelines for sleep recommendations: very short, short, recommended, and long sleep duration. Fan et al. (2020) explain that children with insufficient sleep duration are more likely to be obese, and with an increase in sleep duration the risk of obesity will gradually decrease. Daza et al. (2020) explain the occurrence of a positive association between insufficient sleep and fluctuating glucose data, and negative mood. It contributes to high caloric intake leading

to obesity. In addition, lack of sleep can cause metabolic disorders such as abnormal leptin levels can also lead to obesity (Chaput et al., 2007).

The meta-analysis of 7 cross-sectional articles with a population of children aged 2-18 years showed that children with short sleep duration were 1.83 times more likely to be obese than children with long sleep duration (aOR= 1.83; CI 95%= 1.22 to 2.73; p = 0.003).

People with a sleep duration of <7 hours are 7.70 times more likely to have a risk of obesity compared to those who have sufficient sleep duration (7 to 9 hours). The shorter the duration of sleep, the greater the risk of obesity (Damayanti et al., 2019). The results of several previous studies have shown an inverse association between the risk of sleep duration and the incidence of obesity in children. In line with Fan et al. (2020) very short sleep duration and short sleep duration have a higher risk of obesity (OR= 3.01; CI 95%= 2.19 to 4.15).

When a person does not get enough sleep, the ghrelin hormone in them will increase, while their leptin hormone will decrease. Sleep deprivation can also reduce metabolic processes and calorie burning that should take place while they sleep by 5-20%. Sleep duration that is not in accordance with the needs of children can cause obesity by 89%. Lack of sleep can alter the hormones that regulate hunger, triggering the desire to eat.

Patel dan Hu (2018) explain that children who have short sleep duration can lead to a high sedentary lifestyle and increased energy intake, resulting in obesity in children. Short sleep duration can increase hunger, increase opportunities to eat, thermoregulation changes, and increase fatigue. Increased hunger and increased opportunities to eat will increase energy intake, while changes in thermosregulation and increased fatigue will decrease energy expenditure. Increased energy intake that is not balanced with energy expenditure can lead to obesity.

2. The effect of exercise on the incidence of obesity in children

Physical exercise is one of the popular variables associated with overweight and obesity in children (Dipietro et al., 2020). The meta-analysis of 7 cross-sectional articles with subjects aged 2-18 years showed that children who did not exercise were 0.80 times more likely to be obese compared to children who exercised (aOR= 0.80; CI 95%= 0.59 to 1.09; p= 0.150). This can be known by doing exercise it is unlikely for obesity to occurs.

Some studies explain the association between children who exercise can be protected from obesity. Children who do not do strenuous or moderate exercise have 2.70 times risk compared to children who exercise (aOR=2.70; 95% CI 1.0 to 6.9) (Dereje et al., 2018). Some determinant of weight gain in children in addition to the habit of food consumption that tend to be high in fat and less fiber is lack of physical activity (Gustantia, 2018). Physical activity plays an important role in weight control because calories are burned during exercise or a physical activity (Ibrahim, 2018).

By exercising, the body will experience energy metabolism. All nutritional intake will experience metabolism, and accompanied by exercise, the energy released will be greater and better. Combination with a good diet will result in significant weight loss in people who are obese.

3. The Effect of family income on the Incidence of obesity in Children

The incidence of obesity in children is determined by family income. Adequate family income will support child growth and development because parents can provide for all children's needs both primary and

secondary. Family per capita income that can be explained in this study is family income in a month divided by the number of dependent family members (Wijayanti, 2007).

The meta-analysis of 7 cross-sectional articles with a population of children aged 2-18 years showed that children with high family income were 1.18 times more likely to be obese than children with a low family income (aOR= 1.18; CI 95%= 1.03 to 1.36; p=0.020). The tendency of obesity occurs in children who come from high-income families (OR= 3.8; CI 95%= 1.83 to 7.87) (Parengkuan et al., 2013).

A study by Hidayati et al. (2006) suggests that increased income can also affect the selection of the type and amount of food consumed. Improved prosperity in society followed by improved education can change traditional lifestyles and diets to practical and ready-to-eat foods that can lead to unbalanced nutritional quality. Practical and ready-to-eat diet, especially in big cities in Indonesia, and if consumed irrationally will lead to excessive calorie intake which will cause obesity.

A child with a high-income family makes it easier to meet the ensured nutritional needs. However, when food intake is excessive, it can inflict risk of obesity in children. Excessive energy consumption will force the body to store energy that is not needed, it can be in the form of fat which eventually causes obesity.

AUTHOR CONTRIBUTION

Hanifah as the main researcher who chose the topic, conducted a search for data collection in this study. Arddha Maha Prawitra Dwi Pusspita Dewi, Arinda Mukti Yuhanani, and Jemmi Sastrawijayah conducted data analysis and review of study documents.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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