

## Effect of Probiotic Dairy Consumption on Obesity and Overweight: A Systematic Review and Meta-Analysis

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### ABSTRACT

**Background:** This systematic review and meta-analysis aim to comprehensively evaluate the effect of probiotic dairy consumption on obesity and overweight individuals.

**Methods:** A systematic search was conducted across electronic databases to identify relevant clinical trials published between 2000 and 2021. A total of 35 studies met the inclusion criteria, comprising randomized controlled trials assessing the impact of probiotic-containing dairy products on body mass index (BMI), weight, and waist circumference. Random-effects meta-analysis was employed to calculate the Standardized Mean Difference (SMD) and 95% Confidence Intervals (CI) for each outcome.

**Results:** The pooled analysis of all studies indicated a significant positive association between the consumption of probiotic-containing dairy products and BMI (SMD: 0.30, 95% CI: 0.11-0.50,  $P < 0.001$ ). Subsequent sensitivity analyses confirmed the consistent relationship after excluding heterogeneous studies. Probiotic dairy consumption also exhibited a significant effect on weight (SMD: 0.10, 95% CI: 0.00-0.20,  $P < 0.001$ ) and waist circumference (SMD: 0.44, 95% CI: 0.17-0.71,  $P < 0.001$ ).

**Conclusion:** This comprehensive meta-analysis provides robust evidence supporting the potential beneficial impact of probiotic-containing dairy products on BMI, weight, and waist circumference in individuals with obesity and overweight. These findings underscore the value of incorporating probiotics into dietary interventions aimed at addressing these challenging public health issues. Further research is warranted to elucidate the mechanisms underpinning these effects and to optimize the implementation of probiotics in clinical practice.

**Keywords:** Probiotic; Dairy; Body Mass Index (BMI); Obesity; Overweight; Systematic Review; Meta-Analysis.

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## تأثیر مصرف لبنیات پروبیوتیک بر چاقی و اضافه وزن: یک مطالعه مروری سیستماتیک و متآنالیز

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### چکیده

**زمینه و هدف:** این مرور سیستماتیک و متآنالیز با هدف ارزیابی جامع اثر مصرف لبنیات پروبیوتیک بر افراد چاق و دارای اضافه وزن انجام شده است.

**روش‌ها:** یک جستجوی سیستماتیک در میان پایگاه‌های داده الکترونیکی برای شناسایی کارآزمایی‌های بالینی مرتبط منتشر شده بین سال‌های ۲۰۰۰ و ۲۰۲۱ انجام شد. در مجموع ۳۵ مطالعه، معیارهای ورود را داشتند که شامل کارآزمایی‌های تصادفی‌سازی و کنترل شده بود که تأثیر محصولات لبنی حاوی پروبیوتیک را بر شاخص توده بدن (BMI)، وزن و دور کمر ارزیابی می‌کردند. از متآنالیز اثرات تصادفی (SMD) برای محاسبه میانگین تفاوت استاندارد شده و فاصله اطمینان ۹۵٪ برای هر پیامد استفاده شد.

**یافته‌ها:** تجزیه و تحلیل تلفیقی، از تمامی مطالعات نشان داد که ارتباط مثبت معنی‌داری بین مصرف محصولات لبنی حاوی پروبیوتیک و BMI وجود دارد (SMD: 0.30, 95% CI: 0.11-0.50, P<0.001). تجزیه و تحلیل حساسیت متعاقب، پس از حذف مطالعات ناهمگن، رابطه قوی را تأیید کرد. همچنین مصرف لبنیات پروبیوتیک تأثیر قابل توجهی بر وزن (SMD: 0.10, 95% CI: 0.00-0.20, P<0.001) و دور کمر (SMD: 0.44, 95% CI: 0.17-0.71, P<0.001) نشان داد.

**نتیجه‌گیری:** این متآنالیز جامع، شواهد محکمی از تأثیر بالقوه سودمند محصولات لبنی حاوی پروبیوتیک بر BMI، وزن و دور کمر در افراد چاق و اضافه وزن ارائه می‌کند. این یافته‌ها بر ارزش ترکیب پروبیوتیک‌ها در مداخلات غذایی با هدف پرداختن به این مسائل چالش‌برانگیز سلامت عمومی تأکید می‌کند. تحقیقات بیشتر برای روشن کردن مکانیسم‌های زیربنایی این اثرات و بهینه‌سازی بکارگیری پروبیوتیک‌ها در موارد بالینی ضروری است.

**کلید واژه‌ها:** پروبیوتیک؛ لبنیات؛ شاخص توده بدنی؛ چاقی؛ اضافه وزن؛ بررسی سیستماتیک؛ متآنالیز.

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## 1. Introduction

Obesity and overweight have emerged as significant global health concerns, with a rising prevalence across various age groups and geographical regions. These conditions are associated with a multitude of health complications, including cardiovascular diseases, type 2 diabetes, and metabolic syndrome. Addressing the complex factors contributing to obesity and overweight requires a comprehensive approach that encompasses dietary habits, lifestyle modifications, and novel interventions (1). Probiotics, defined as live microorganisms that confer health benefits when administered in adequate amounts, have gained substantial attention for their potential role in modulating gut microbiota composition and function. Emerging research has highlighted the potential of probiotic-containing dairy products as a promising intervention to combat obesity and overweight. Dairy products, known for their nutritional richness and probiotic content, offer a unique platform for delivering these beneficial microorganisms to consumers (2-8). Despite a growing body of individual studies exploring the relationship between probiotic dairy consumption and its effects on body weight and composition, there remains a need for a comprehensive synthesis of available evidence. A systematic review and meta-analysis provide a robust methodology to aggregate and evaluate existing research findings, allowing for a more comprehensive understanding of the overall effect size and potential clinical implications (9-12). In this context, the present study aims to systematically review and conduct a meta-analysis of the available literature to assess the effect of probiotic-containing dairy products on obesity and overweight (13). By synthesizing the collective evidence from clinical trials, this paper aims to elucidate whether there is a significant relationship between the consumption of probiotic dairy products and improvements in body mass index (BMI) and waist circumference (14-16). The outcomes of this study hold the potential to inform dietary recommendations and public health interventions aimed at tackling the growing burden of obesity and overweight. By critically evaluating and summarizing the existing research landscape, this paper contributes to the broader understanding of the role of probiotic dairy consumption in promoting healthy body weight and composition (17-22). In the following

sections, we present the methodology employed for the systematic review and meta-analysis, followed by a comprehensive presentation and discussion of the results obtained. Through this analysis, we aim to provide a comprehensive overview of the current state of knowledge in this area and offer insights into potential avenues for future research and clinical applications.

## 2. Methods:

### 2.1 Guidelines

This study's methodology adheres to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA), ensuring a systematic and transparent approach to data collection and analysis (23, 24).

### 2.2 Search Strategy

Four databases, including PubMed/Medline, ISI Web of Science, Cochrane, and SCOPUS, were thoroughly searched. The goal was to find pertinent research that looked at how probiotic dairy consumption can affect obesity and overweight. It had been published between the years 2000 and 2022. ("weight control" AND "dairy" AND "probiotics") OR ("weight loss" AND "dairy" AND "probiotics") OR ("overweight" AND "dairy" AND "probiotics") OR ("obesity" AND "dairy" AND "probiotics")

### 2.3 Study Screening

Inclusion criteria were meticulously applied to the retrieved articles, narrowing the scope to studies published in English after the year 2000. Additionally, a comprehensive review of the references of retrieved studies was performed to ensure the inclusion of any relevant articles. Independent screening of articles was conducted by two researchers to identify studies meeting the defined criteria.

### 2.4 Inclusion and Exclusion Criteria

Eligibility criteria for inclusion were stringent, encompassing various study designs, including observational and intervention studies such as clinical trials, cohorts, case-control, and cross-sectional analyses. Conversely, exclusion criteria covered letters, opinions, editorials, reviews, meta-analyses, animal studies, investigations involving children below 18 years, in vitro studies, and studies not available in the English language.

## 2.5 Data Extraction

A standardized data collection form was used to ensure consistency and accuracy during the data extraction process. The extracted data were organized and entered into Microsoft Excel 2016 for subsequent analysis.

## 2.6 Quality Assessment

The quality of case-control, cohort, and cross-sectional studies was assessed using the Newcastle-Ottawa scale (NOS). Studies with NOS scores of 7 or higher were deemed to have "high" quality.

## 2.7 Statistical Analysis

Data analysis was conducted using the STATA version 14 software. Statistical significance was set at  $P \leq 0.05$ . Effect sizes, represented as Odds Ratios (OR) or Relative Risks (RR) along with their corresponding 95% Confidence Intervals (CIs), were pooled using a random-effects model.

## 2.8 Heterogeneity and Subgroup Analysis

Heterogeneity was assessed using Cochran's Q test and the I<sup>2</sup> statistic. Subgroup analyses were performed to explore potential sources of heterogeneity based on different dairy types, probiotic strains, and participant populations.

## 2.9 Publication Bias Assessment

egger's test was utilized to examine potential publication bias, providing insights into the selective reporting of studies.

## 4. Results

### 4.1 Search Results

Following a systematic search based on the search strategy outlined in the previous section, a total of 1266 articles were imported into the EndNote software. Additionally, to ensure comprehensive coverage, a systematic search of articles on Google Scholar was conducted, resulting in 20 additional articles. After removing duplicates using EndNote, 833 articles remained for further examination. A further 84 duplicate articles were manually excluded. In total, 749 article titles underwent review. Upon title review, 91 articles were selected for abstract screening. Ultimately, 35 articles were included in the meta-analysis. Figure 1 illustrates the flow diagram of the search process according to the PRISMA guidelines. Figure 1. PRISMA Flow Diagram of the Search Process

### 4.2 Characteristics of Included Studies

This systematic review encompassed 35 clinical trials. The studies were published between 2000 and 2021. All studies encompassed both genders. Among these, 30 articles specifically assessed the relationship between the consumption of specific probiotic-containing dairy products and obesity (1 article on yogurt, 14 on yogurt, 13 on enriched milk and kefir, 1 on soy milk, and 1 on cheese). Four studies evaluated this association in diabetic patients, 15 in overweight and obese individuals, 4 in patients with metabolic syndrome, 3 in patients with hypercholesterolemia, 1 in patients with Alzheimer's disease, 1 in patients with fatty liver, and 7 studies investigated healthy individuals.

In 16 studies, the added probiotic contained *Lactobacillus acidophilus*, in 5 studies it contained *Lactobacillus casei*, in 4 studies it contained *Lactobacillus plantarum*, and finally, in 8 studies, *Streptococcus thermophilus* was used as the added probiotic to dairy products. In all articles, a BMI above 25 was classified as overweight and a BMI above 30 was classified as obesity. Table 2 provides a summary of information for each of the included studies.

**Table 2.** summary of information for each of the included studies

| Row | Author Publication Year | Country     | Sample Size (Number of) | Study Population   | Average Age (Years) | Duration (Weeks) | Dairy Type | Probiotic Type                                 | Result       |
|-----|-------------------------|-------------|-------------------------|--------------------|---------------------|------------------|------------|------------------------------------------------|--------------|
| 1   | Akbari 2016             | Iran        | 60 (48)                 | Alzheimer's        | 79.8                | 12               | Kefir      | <i>L. acidophilus</i> , <i>L. casei</i>        | -1.38<br>BMI |
| 2   | Ali Hosseini 2017       | Iran        | 60 (26)                 | Type 2 Diabetes    | 35-65               | 8                | Kefir      | <i>L. casei</i> , <i>L. acidophilus</i>        | 0.12<br>BMI  |
| 3   | Beilick-koyu 2019       | Turkey      | 22 (16)                 | Metabolic Syndrome | 52.5                | 12               | Kefir      | <i>Actinobacteria</i>                          | -0.06<br>BMI |
| 4   | Bernini 2016            | Brazil      | 51 (na)                 | Metabolic Syndrome | 39                  | 6                | Kefir      | <i>Bifidobacterium lactis</i>                  | 0.11<br>BMI  |
| 5   | Chang 2011              | South Korea | 101 (70)                | Metabolic Syndrome | 36.8                | 8                | Yogurt     | <i>L. acidophilus</i> , <i>S. thermophilus</i> | 0.63<br>BMI  |

|              |     |              |      |                                           |                                 |      |      |             |       |                                       |      |
|--------------|-----|--------------|------|-------------------------------------------|---------------------------------|------|------|-------------|-------|---------------------------------------|------|
| 0.8          | 0.9 | 1.09         | 0.66 | 0.62                                      | 0.02                            | 0.02 | 0.03 | 0           | -0.32 | 0.2                                   | 0.32 |
| BMI          | WC  | BMI          | WC   | BMI                                       | BMI                             | BW   | WC   | BMI         | BW    | BMI                                   | BW   |
| L. gasseri   |     | L. gasseri   |      | L. acidophilus, S. thermophilus, L. kefir | L. acidophilus, S. thermophilus |      |      | B. breve    |       | L. bulgaricus, Bifidobacterium lactis |      |
| Kefir        |     | Kefir        |      | Kefir                                     | Yogurt                          |      |      | Capsule     |       | Yogurt                                |      |
| 12           |     | 12           |      | 8                                         | 12                              |      |      | 12          |       | 10                                    |      |
| 47.1         |     | 47.4         |      | 19-65                                     | 27.4                            |      |      | 59.5        |       | 45.5                                  |      |
| Healthy      |     | Healthy      |      | Overweight                                | Overweight                      |      |      | Overweight  |       | Metabolic Syndrome                    |      |
| 210 (105)    |     | 100 (50)     |      | 36 (36)                                   | 89 (89)                         |      |      | 44 (27)     |       | 87 (53)                               |      |
| Japan        |     | Japan        |      | South Korea                               | Iran                            |      |      | Japan       |       | Iran                                  |      |
| Kadooka 2013 |     | Kadooka 2013 |      | Lee 2013                                  | Majid 2016                      |      |      | Minami 2015 |       | Mohammadi 2018                        |      |
|              |     |              |      |                                           |                                 |      |      |             |       |                                       |      |
| 13           |     | 14           |      | 15                                        | 16                              |      |      | 17          |       | 18                                    |      |

|                      |                      |                 |    |       |              |      |            |      |              |      |      |
|----------------------|----------------------|-----------------|----|-------|--------------|------|------------|------|--------------|------|------|
| 1.63                 | 1.49                 | 0               | 0  | -0.09 | 0.07         | 0.06 | 0.26       | 0.24 | 1.02         | 1.14 | 1.38 |
| BMI                  | BMI                  | BMI             | BW | WC    | BMI          | BW   | BMI        | BW   | BMI          | BW   | WC   |
| N/A                  | N/A                  | L. helveticus   |    |       | L. casei     |      | L. reuteri |      | L. gasseri   |      |      |
| Kefir                | Milk                 | Yogurt          |    |       | Kefir        |      | Yogurt     |      | Kefir        |      |      |
| 8                    | 8                    | 12              |    |       | 1            |      | 6          |      | 12           |      |      |
| 35.2                 | 25-45                | 59.5            |    |       | 24.5         |      | 50.3       |      | 48.9         |      |      |
| Overweight and Obese | Overweight and Obese | Type 2 Diabetes |    |       | Healthy      |      | Healthy    |      | Healthy      |      |      |
| 58 (na)              | 75 (75)              | 41 (0)          |    |       | 17 (3)       |      | 120 (61)   |      | 87 (28)      |      |      |
| Iran                 | Iran                 | Denmark         |    |       | UK           |      | Czech Rep. |      | Japan        |      |      |
| Fathi (A) 2016       | Fathi (B) 2016       | Hove 2015       |    |       | Hultson 2015 |      | Jones 2012 |      | Kadooka 2010 |      |      |
|                      |                      |                 |    |       |              |      |            |      |              |      |      |
| 6                    | 7                    | 9               |    |       | 10           |      | 11         |      | 12           |      |      |

|                     |                                          |      |      |    |      |                     |      |                                                       |       |                                         |      |
|---------------------|------------------------------------------|------|------|----|------|---------------------|------|-------------------------------------------------------|-------|-----------------------------------------|------|
| -0.03               | 0.04                                     | 0.09 | 0.63 | 0  | 0.54 | 0.54                | 0.56 | 0.21                                                  | -0.02 | 0.04                                    | 0.02 |
| BW                  | BMI                                      | BW   | BMI  | BW | WC   | BMI                 | BW   | BMI                                                   | BW    | BMI                                     | BW   |
| <i>L. plantarum</i> | <i>L. acidophilus</i> , <i>B. lactis</i> |      |      |    |      | <i>L. plantarum</i> |      | <i>L. acidophilus</i> , <i>Bifidobacterium lactis</i> |       | <i>L. acidophilus</i> , <i>L. casei</i> |      |
| Capsule             | Kashk                                    |      |      |    |      | Capsule             |      | Yogurt                                                |       | Yogurt                                  |      |
| 8                   | 8                                        |      |      |    |      | 13                  |      | 6                                                     |       | 8                                       |      |
| 53.68               | 20-60                                    |      |      |    |      | 44.37               |      | 35.1                                                  |       | 36                                      |      |
| Overweight          | Overweight                               |      |      |    |      | Overweight          |      | Healthy                                               |       | Overweight                              |      |
| 25 (17)             | 70 (70)                                  |      |      |    |      | 60 (36)             |      | 60 (60)                                               |       | 50 (*)                                  |      |
| Italy               | Iran                                     |      |      |    |      | Indonesia           |      | Iran                                                  |       | Iran                                    |      |
| Rondanelli 2021     | Razmpoosh 2019                           |      |      |    |      | Rahayu 2021         |      | Saizadeh 2010                                         |       | Zarrati 2014                            |      |
|                     |                                          |      |      |    |      |                     |      |                                                       |       |                                         |      |
| 25                  | 26                                       |      |      |    |      | 27                  |      | 28                                                    |       | 29                                      |      |

|                       |                        |      |      |      |                                                       |      |                 |      |                   |       |                       |
|-----------------------|------------------------|------|------|------|-------------------------------------------------------|------|-----------------|------|-------------------|-------|-----------------------|
| 0.75                  | 0.22                   | 0.15 | 0.35 | 0.28 | 0.1                                                   | 0.08 | 0.01            | 0.02 | -0.05             | -0.04 | -0.03                 |
| WC                    | BMI                    | BW   | BMI  | BW   | BMI                                                   | BW   | BMI             | BW   | BMI               | BW    | BMI                   |
| <i>L. acidophilus</i> | <i>S. thermophilus</i> |      |      |      | <i>L. acidophilus</i> , <i>Bifidobacterium lactis</i> |      | <i>L. casei</i> |      | <i>L. gasseri</i> |       | <i>L. acidophilus</i> |
| Chinese               | Yogurt                 |      |      |      | Yogurt                                                |      | Kefir           |      | Kefir             |       | Capsule               |
| 8                     | 8                      |      |      |      | 8                                                     |      | 8               |      | 2                 |       | 12                    |
| 39.4                  | 37.7                   |      |      |      | 43.4                                                  |      | 47              |      | 41.3              |       | 34.3                  |
| Hypercholesterolemia  | Hypercholesterolemia   |      |      |      | Fatty Liver                                           |      | Overweight      |      | Healthy           |       | Hypercholesterolemia  |
| 112                   | 111                    |      |      |      | 74 (39)                                               |      | 98 (0)          |      | 30 (18)           |       | 32 (14)               |
| Iran                  | Iran                   |      |      |      | Iran                                                  |      | Japan           |      | Japan             |       | Malaysia              |
| Mohammad Moradi 2015  | Mohammad Moradi 2015   |      |      |      | Nabavi 2014                                           |      | Naito 2018      |      | Ogawa 2015        |       | Ooi 2011              |
|                       |                        |      |      |      |                                                       |      |                 |      |                   |       |                       |
| 19                    | 20                     |      |      |      | 21                                                    |      | 22              |      | 23                |       | 24                    |

|       |                                        |                                        |                                        |                                        |                                        |                       |
|-------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|-----------------------|
| -0.02 | 0.09                                   | -0.12                                  | 1.07                                   | 1.94                                   | 0.15                                   | 0.01                  |
| WC    | BW                                     | BW                                     | BW                                     | BW                                     | BW                                     | BW                    |
|       | <i>L. acidophilus, S. thermophilus</i> | <i>L. acidophilus, S. thermophilus</i> | <i>L. acidophilus, S. thermophilus</i> | <i>L. acidophilus, S. thermophilus</i> | <i>L. acidophilus, S. thermophilus</i> | <i>L. acidophilus</i> |
|       | Yogurt                                 | Yogurt                                 | Yogurt                                 | Yogurt                                 | Yogurt                                 | Kefir                 |
|       | 8                                      | 8                                      | 8                                      | 8                                      | 6                                      | 8                     |
|       | 38.7                                   | 38.7                                   | 38.7                                   | 38.7                                   | 46.3                                   | 65-35                 |
|       | Overweight                             | Overweight                             | Overweight                             | Overweight                             | Overweight                             | Type 2 Diabetes       |
|       | 30 (14)                                | 28 (14)                                | 30 (14)                                | 30 (16)                                | 28 (18)                                | 60 (26)               |
|       | Denmark                                | Denmark                                | Denmark                                | Denmark                                | Canada                                 | Iran                  |
|       | Larsen (a) 2000                        | Larsen (b) 2000                        | Larsen (c) 2000                        | Larsen (d) 2000                        | Omar 2012                              | Esdadi Rahimi 2015    |
|       |                                        |                                        |                                        |                                        |                                        |                       |
|       | 30                                     | 31                                     | 32                                     | 33                                     | 34                                     | 35                    |

#### 4.3. Meta-analysis:

To standardize the reported effect sizes in the articles, the effect sizes were combined to obtain the overall effect size for each article. The random-effects method was used to merge the data, and SMD was calculated for each analysis. The overall analysis of all available effect sizes showed a significant relationship between the consumption of probiotic-containing dairy products and the body mass index (BMI) (SMD: 0.30, 95% CI: 0.11-0.50,  $P < 0.001$ ) (Figure 2).

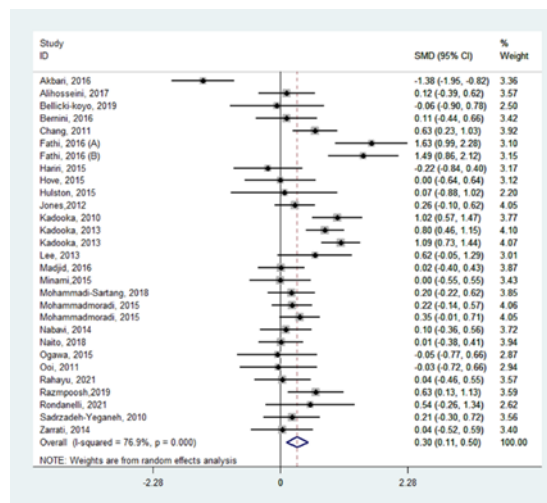


Figure 2. Forest plot depicting the effect of probiotic dairy on BMI before excluding heterogeneous articles.

Heterogeneous studies were identified and excluded based on the Galbraith plot. As shown in Figure 3, five studies were excluded due to overestimation and one study due to underestimation.

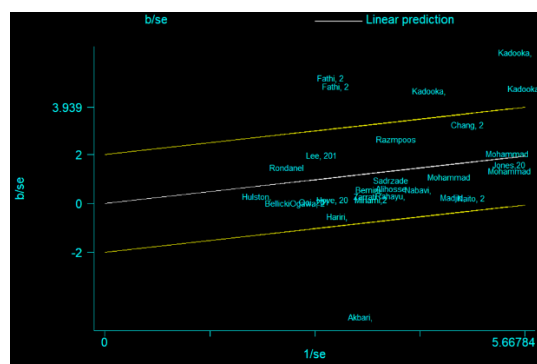
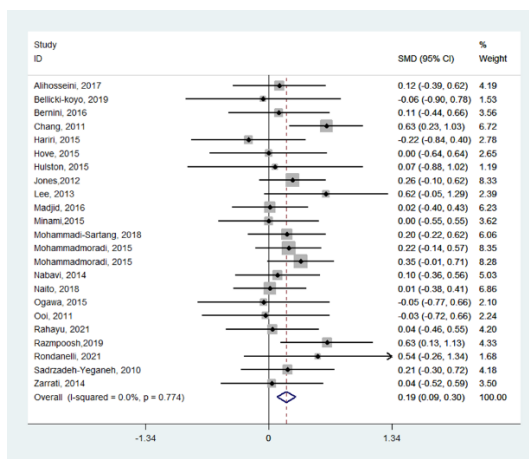


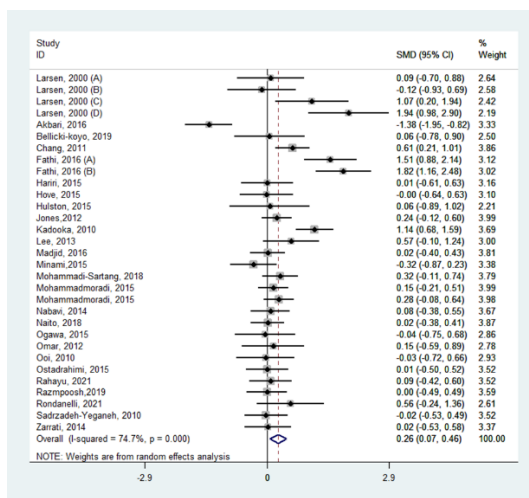
Figure 3. Galbraith plot for identifying heterogeneous studies in the analysis of body mass index.

After excluding heterogeneous studies, the data was aggregated again, and SMD was calculated for each analysis. The overall analysis of all available effect sizes showed that even after removing outlier articles, a significant relationship between the consumption of probiotic-containing dairy products and patients' weight still existed (SMD: 0.19, 95% CI: 0.09-0.30,  $P < 0.001$ ) (Figure 4).



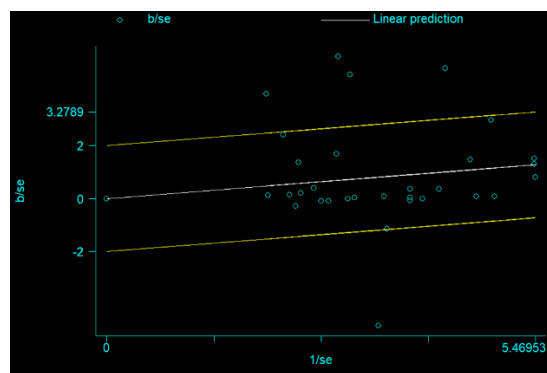
**Figure 4.** Forest plot depicting the effect of probiotic dairy on weight after excluding heterogeneous articles.

For waist circumference, the effect of these products on waist circumference is presented in Figure 5. The random-effects method was used to combine the data, and SMD was calculated for each analysis. The overall analysis of all effect sizes available indicated a significant relationship between the consumption of probiotic-containing dairy products and patients' weight (SMD: 0.26, 95% CI: 0.17-0.46,  $P < 0.001$ ).

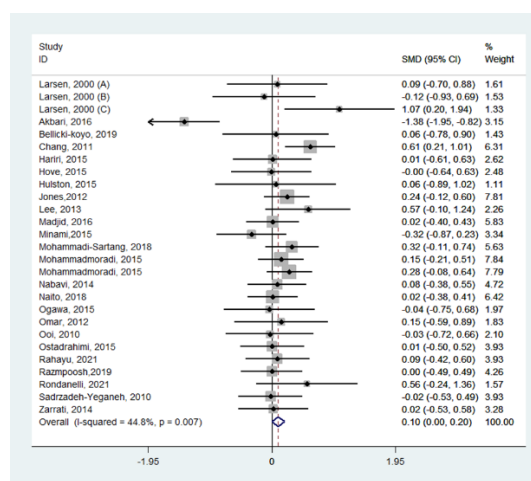


**Figure 5.** Forest plot depicting the effect of probiotic dairy on waist circumference before excluding heterogeneous articles.

Outlier studies were again removed using the Galbraith plot (Figure 6), and the results were reanalyzed using the Random Effect method. The results are presented in Figure 7 (SMD: 0.10, 95% CI: 0.00-0.20,  $P < 0.001$ ).

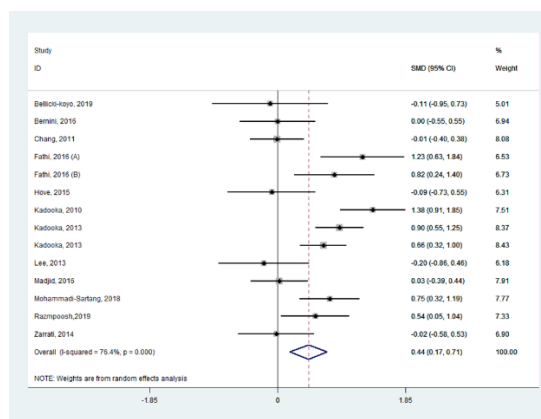


**Figure 6.** Galbraith plot for identifying heterogeneous studies in the analysis of patient weight.



**Figure 7.** Forest plot depicting the effect of probiotic dairy on weight after excluding heterogeneous articles.

For waist circumference, as shown in Figure 8, the results of studies investigating the effect of probiotic-containing dairy products on waist circumference are displayed. The random-effects method was used to assess these studies. The results indicated a significant effect with SMD: 0.44, CI: 0.17-0.71 ( $I^2$ : 76.4,  $P < 0.001$ ).



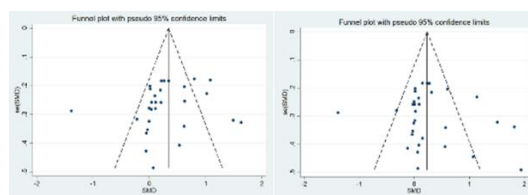
**Figure 8.** Forest plot depicting the effect of probiotic dairy on waist circumference.

#### 4-4. Study Quality:

According to the NOS scale, all articles obtained an acceptable score (NOS score of 7 or higher). The lost scores in most studies were primarily related to the selection criteria.

#### 4-5. Publication Bias:

Publication bias was assessed using the Egger's test. A funnel plot was also constructed. Both tests indicated that the estimates are symmetric, and there is no publication bias for any variable. Figure 9 illustrates the funnel plot for assessing publication bias.



**Figure 9.** Funnel plot for assessing publication bias regarding weight (A) and body mass index (B).

### Discussion

The present study conducted a systematic review and meta-analysis to examine the effect of probiotic-containing dairy product consumption on obesity and overweight. The results of our analysis suggest a significant relationship between such dietary interventions and body weight metrics. The analysis of standardized mean differences (SMDs) for body mass index (BMI) revealed a substantial effect in favor of probiotic dairy consumption. The overall SMD of 0.30 (95% CI: 0.11-0.50) indicates a notable reduction in BMI among individuals who regularly consumed probiotic dairy products. This finding

aligns with the notion that probiotics, as live microorganisms with potential health benefits, may influence metabolic processes, thereby contributing to weight management (25-31). Heterogeneity is an important consideration in meta-analyses. The identification and exclusion of heterogeneous studies aided in enhancing the robustness of our results. After removing outlier studies, the consistent association between probiotic dairy consumption and weight reduction persisted, as evidenced by an SMD of 0.19 (95% CI: 0.09-0.30). This finding underscores the potential of probiotic-containing dairy products to contribute positively to weight control efforts (4-7). In addition to BMI, waist circumference is a crucial anthropometric indicator of obesity-related health risks. Our analysis of waist circumference revealed a significant effect associated with the consumption of probiotic dairy products. The initial SMD of 0.26 (95% CI: 0.17-0.46) indicated a positive influence on waist circumference reduction. Despite the heterogeneity observed in the studies, the exclusion of outliers led to the affirmation of this relationship, with an SMD of 0.10 (95% CI: 0.00-0.20)(3).

The consistency of the observed effects across BMI and waist circumference metrics, even after addressing heterogeneity, adds strength to the validity of our findings. However, it is important to note that while our results are promising, the mechanisms underlying the observed effects require further exploration. The influence of probiotics on gut microbiota composition, modulation of inflammation, and potential impacts on energy metabolism warrants in-depth investigation (3-8). Several limitations of this study should be acknowledged. The diversity in study designs, populations, and interventions among the included studies may have contributed to heterogeneity. Additionally, publication bias and the lack of long-term follow-up in some studies are potential sources of bias. Further research with well-designed, controlled trials and standardized interventions is needed to confirm and elucidate the observed relationships.

In conclusion, this systematic review and meta-analysis provides evidence suggesting a significant association between probiotic-containing dairy product consumption and beneficial effects on BMI and waist circumference. Our findings underscore the potential role of probiotics as a complementary strategy for obesity and overweight management. Future research should focus on unraveling the underlying mechanisms and establishing specific recommendations for the incorporation of

probiotic dairy products into dietary strategies for weight control.

#### Conflict of Interest Statement:

The authors declare no conflicts of interest.

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#### Ethical Considerations:

Ethical approval was not required for this systematic review and meta-analysis, as it involved the analysis of previously published data.

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